A MANUAL OF PRACTICAL X-RAY WORK

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AUTHOR'S FOREWORD AND ACKNOWLEDGMENT

SINCE the first appearance of this book in 1908 radiology, as an auxiliary to medicine and surgery, has developed to a remarkable extent and in many directions.

A second edition of the book, published in 1917, suffered in scope and quality on account of the war conditions then existing.

The further demand for revision at the present time is gratifying testimony to the continued usefulness of the book, and the opportunity has been taken to bring the whole subject-matter thoroughly up to date.

Every branch of radiological work has been surveyed and a condensed account, simple but complete, is presented, which it is trusted will serve as an efficient introduction for the uninitiated and as a reference for the inexperienced.

Diagnosis occupies a proportionately greater section of the book than in previous editions, ranging as it does from the earliest work on fractures and gross bony abnormalities to the latest essay in elucidation of obstetrical problems.

At the same time, application of physical theory and description of technical apparatus, to be treated satisfactorily, requires as much, or more, space than formerly, despite the excision of obsolete types and certain details no longer relevant; so that the resultant volume shews a considerable increase in size as compared with preceding editions.

It is trusted that its value as an educative medium may prove to be at least equally enhanced, and, from consideration of the valuable assistance and collaboration which he has had the privilege of enlisting in his labours, the author feels much confidence in the issue.

The inclusion, by regulation of the General Medical Council, of radiology as a necessary subject of study in the curriculum of all medical students seeking a British qualification, gives that subject a definite status that it well merits, and the potential usefulness of this book as a students' text-book on the subject has been kept specially in view in determining its character and scope.

Sufficient has also been included to furnish a comprehensive introduction to study for a radiological diploma and to give practising physicians and surgeons an intelligent conception of the possibilities—and the limitations—of radiological assistance.

An author's indebtedness to others in the preparation of such a work as this is more easy to realise than to state.

Deprived by circumstances of the valuable and highly appreciated assistance of Dr. Arthur, my colleague in the original edition, I have been more than fortunate in securing in this edition the collaboration of Sir Archibald Reid and of Mr. F. J. Harlow, colleagues with me in the War Office X-ray Committee.

With more British radiologists than I can here enumerate the work of that committee gave me the privilege of friendship and acquaintance, and to all of them I owe a debt for inspiration or assistance, direct or indirect, in the compilation of the following pages. It has been no light task, but if the result may be considered by my colleagues as a fitting contribution to the rapidly materialising school of British radiology, my efforts are more than compensated.

To Sir Archibald Reid I owe more than I can adequately acknowledge for never-failing advice and constructive criticism, and for provision of most of the radiograms reproduced in the later sections of the book.

To Mr. Harlow is due the revision of the earlier sections, so far as they deal with physical problems, and those who know him will readily understand the pleasure and confidence with which I availed myself of that assistance.

To Dr. Bertram Shires and to Dr. Geoffrey Fildes I am deeply indebted for various assistances and for radiograms reproduced, whilst to Mr. A. L. Townsend my warmest thanks are due for hints regarding the section on photography and for valuable assistance in other matters.

To Sir Henry Gauvain I am indebted for Figs. 307 and 308 and for notes regarding them. Dr Hebert most helpfully discussed with me an interesting collection of chest radiograms and lent several for reproduction.

Dr. Walker Overend kindly and readily assented to the reproduction, in Chapter X, of several illustrations from his book on "Radiography of the Chest," a common publisher for the two works making the exchange an easy one. To that publisher I owe apology for straining of his patience and thanks for his unfailing courtesy and accommodation; whilst to Miss Turner, who dealt executively with the mass of manuscript and blocks and repeatedly reduced chaos to order, I offer my sincere personal thanks.

The sources of other illustrations, such as those from Dr. Salmond, Dr. Scott, Dr. Morison, and Dr. Thurstan Holland, are alluded to in their context; if I have inadvertently omitted any acknowledgment, I trust the omission may be recognised as entirely unintentional and that it may accordingly be forgiven.

JOHN MUIR.

RADLETT, HERTS,

January, 1924.

SYNOPSIS OF CONTENTS

A MANUAL

OF

PRACTICAL X-RAY WORK

INTRODUCTORY

Electrical Terms—Evolution of the X-ray Tube

To one already acquainted with radiology it matters little in what sequence its various factors or problems are considered. He will seek out for himself the parts in which he may be specially interested, or the points on which he may desire enlightenment.

To others, however, it is of importance that the various parts should be treated in orderly sequence: this has been borne in mind, and it is endeavoured so to present the subject in the present work.

As a general plan of the work, it has been thought fit to begin by considering the immediate production of X rays; next, to consider the remoter means of their production; then to proceed to the discussion of their practical uses.

Like so many other processes utilised by the medical profession, radiology is based on the results of painstaking research in pure science—research initially remote from any suggestion of therapeutic issue.

For the benefit of those who have not previously studied the subject, and whose acquaintance with physics may be somewhat remote, there is introduced here a number of *definitions and explanations* of electrical terms employed, followed by a few notes on the *evolution of the X-ray tube*. The importance of a thorough, even though elementary, understanding of these introductory notes will be appreciated in reading the later sections of the book, where their practical application is dealt with.

Electrical Terms.

A current of electricity will flow in a circuit consisting of conductors of electricity if there is an electro-motive force (written briefly, E.M.F.) in that circuit.

Such electro-motive force may be derived from chemical action, as in batteries or cells, or may be produced by causing a conductor to move in a magnetic field, as in a dynamo machine, and in other ways.

The flow of electricity in such a circuit may conveniently be compared with the flow of water in a pipe, due to motive force supplied by the action of a pump. In any section of such a pipe the flow may be regarded as due to the difference between the pressures at the two ends of the section, which pressures may be measured. Similarly, in electricity reference is made to the potential difference (written briefly, P.D.), or electrical pressure between the ends of the conductor.

Ohm's law governs the flow of a current of electricity in the circuit, and may be stated thus:—

The current flowing through a conductor is proportional to the P.D. between its ends.

Alternatively, if applied to the whole circuit, instead of to a portion only, *the current flowing through the circuit is proportional to the E.M.F. in that circuit.*

The ratio of the E.M.F. to the current is thus a constant for any given circuit; or, alternatively, the ratio of the P.D. to the current is a constant for any given portion of the circuit, and is known as the **resistance** of the circuit or of the portion of the circuit.

Symbolically, the law is stated thus:—

$$C = \frac{E}{R} \text{ or } C = \frac{V}{R}$$

Units.—When a current of electricity is passed through a solution of silver nitrate, silver is deposited on the conductor by which the current leaves (called the kathode) in amount proportional to the current and the time. The *unit of current* is therefore defined as that current which causes the deposition of a certain weight of silver per second, and is named the **ampere.** Instruments used for current measurement are called ammeters, or, for small currents, milliammeters.

The *unit of resistance* is termed the **ohm**; it is the resistance of a tube of mercury of certain weight and dimensions. The

resistance of a conductor is proportional to its length, inversely proportional to its cross section, and depends upon the nature of the conducting material. Copper is a specially good conducting metal, and is therefore largely used in electrical circuits. If resistance is required, it is found convenient to use certain alloys such as German silver, manganin, eureka or nichrome. Resistance usually increases with rise in temperature; several of the above alloys are employed on account of their durability and small change of resistance with change of temperature. Two or more resistances may be connected together in either of two different ways.

If joined end to end, as in Fig. 1, they are said to be *in series*, the main current passing through both; if joined as in Fig. 2, they are said to be *in parallel*, the current dividing

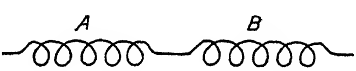


Fig. 1.—Resistances in Series.

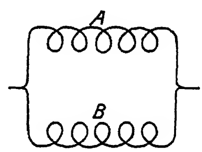


Fig. 2.—Resistances in Parallel.

between the two. In series the total resistance is the sum of the two; in parallel:—

$$\frac{1}{R} = \frac{1}{A} + \frac{1}{B}.$$

The *unit of E.M.F. or P.D.* is the **volt**, which is that P.D. across a resistance of one ohm which will cause a current of one ampere to be sent through the resistance. An instrument for the measurement of P.D. is termed a voltmeter.

To measure current passing in a circuit an ammeter is included directly in that circuit, but a voltmeter is never so included. It is connected, as in a bye-pass, to any two given points of a circuit, when the P.D. is required between the two given points. The instrument may also be connected up to a cell or to the mains of an electric supply, before current flows, in order to measure the P.D. available.

The rate at which an electric current can do mechanical work (or develop heat in a resistance) is its power; *the unit of power* is termed the **Watt**, which is the power involved when one ampere flows through a P.D. of one volt.

Power is calculated thus :—

W (in Watts) = C (in amperes) × V (in volts).

746 Watts = 1 horse-power—written H.P.

1000 Watts = 1 kilowatt.

When the factor of time comes into consideration energy is spoken of, and *the unit of energy* commonly used is the **kilowatt-hour.**

J (in kilowatt-hours) = W (in kilowatts) × T (in hours).

A **direct or continuous** voltage or current is one which remains always in the same direction and is constant in amount.

Alternating current does not remain constant, but alternates in direction periodically—the flow in each direction taking place usually some fifty or sixty times a second.

The number of complete alternations per second is termed

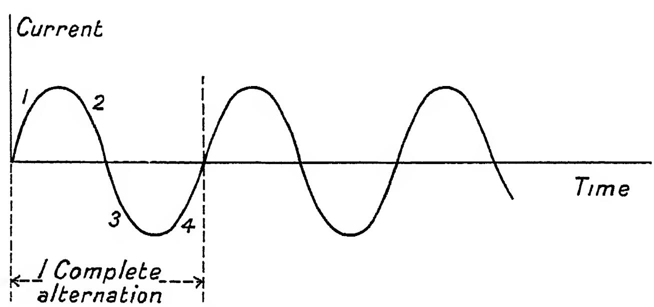


Fig. 3.—Graph of Alternating Current.

the *frequency* or *periodicity.* The simplest form of alternating current is that in which the voltage, and consequently the current, varies sinusoidally, as indicated in the graph in Fig. 3, in which the current is shewn vertically and the time horizontally.

It will be seen from the graph that during one complete alternation the current (1) starts from zero and rises to a maximum, (2) decreases to zero again, (3) reverses its direction and increases to a maximum of opposite sign, and (4) decreases to zero again.

Various forms of instrument are employed for measuring alternating current, and those do not indicate the maximum values reached, but rather a summation or average, expressed in terms of direct current of equivalent heating effect.

This reading is known as the *root mean square*, being the square root of the average value of the square of the current at

every instant in a cycle, and is written as "current R.M.S. value."

The simple form of alternating current indicated by the graph in Fig. 3 is known as *single phase*, but it is possible to arrange two or more such circuits with certain parts in common in which alternating currents will flow which are not in step. The resultant alternating current is known as two-phase, three-phase, etc. Generators are specially constructed to generate those so-called *polyphase currents* which have distinct advantages for power purposes.

In X-ray work, however, single-phase currents are desired, and where a polyphase supply exists arrangement should be made to use one phase only.

Insulation.—All metals and solutions of metallic salts are conductors of electricity in greater or less degree, but many substances offer considerable resistance to the flow of current through them. Substances which refuse to conduct electricity are said to be *insulators*, and these materials are of extreme importance in practical applications of electricity, since obviously to control the flow of electricity it must be possible to prevent its flow when necessary. In X-ray work, where very high voltages are employed, good insulators are especially necessary.

Quantity of Electricity and Capacity.—Only the flow of electricity has so far been considered. If, however, a conductor be insulated from other conductors, and its potential be raised by momentary contact with a source of high potential, the conductor receives a charge of electricity and becomes a store for it.

The quantity of electricity stored by an insulated conductor, when its potential is raised by one volt, is known as its *capacity*.

Quantity is measured in *coulombs*, one **coulomb** being the quantity of electricity involved in the passage of one ampere for one second.

The capacity of the insulated conductor, however, depends upon the nearness to it of other conductors at different potentials. By arranging two conductors of large area very near to each other, one being connected to earth and the other insulated, the capacity may become relatively very large. Such an arrangement is known as a **condenser**, and is shown diagramatically in Fig. 4, in which the plate B is a conductor connected to earth, and the plate A another conductor, insulated from B by the intervening nonconducting layer C.

Condensers have the faculty of storing electricity, the capacity being the quantity of electricity required to produce a difference of potential of one volt between the plates

The *unit of capacity* is the **micro-farad.**

The capacity is found to depend upon the distance between the plates, being greater as the distance is less, and it further depends upon the character of the insulator used The insulator in a condenser (C in Fig 4) is called the *dielectric*, and its capacity-raising property is called its *specific inductive capacity*

Another feature to be considered in a dielectric is the height of voltage it will stand per unit of thickness before it may break down and become a conductor, where high potentials are employed this is of considerable importance

Evolution of the X-ray Tube.

The present X-ray gas tube has been evolved from the older Geissler or vacuum discharge tube, consisting of a glass

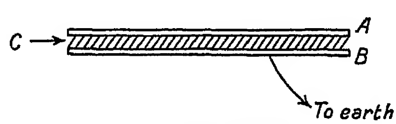


FIG. 4 —CONDENSER.

tube into the ends of which metal pieces called electrodes are sealed

In a discharge tube, as the pressure is reduced below that of the atmosphere, the electrical resistance for a time gradually decreases, and, instead of the ordinary thin spark obtained at atmospheric pressure, the discharge fills the whole tube with characteristic illumination depending upon the degree of exhaustion As exhaustion proceeds, dark spaces appear in the tube, gradually encroaching upon the illuminated areas At a certain stage in the exhaustion, at about $\frac{1}{50}$ mm pressure, further reduction of gas pressure causes an increase of electrical resistance until finally no discharge is possible across the tube. This is called the critical pressure and is dependent upon the distance between the electrodes As this stage is approached, the luminosity in the gas gradually disappears till it appears only in front of the anode (the electrode by which the current is spoken of as entering the tube)

A fluorescence of the glass walls of the tube now becomes apparent, the colour depending upon the character of the glass.

Sir William Crookes, about 1891, studied the phenomena of the discharge in highly exhausted tubes, the pressure in the tubes he worked with being reduced to about $\frac{1}{1000}$th part of a mm (*i e*, about one-millionth part of an atmosphere) The fluorescence was found to be due to a bombardment of the interposed object by streams of negatively charged particles, moving normally from the kathode of the tube at a very high velocity Such particles are now spoken of as electrons In tubes such as were experimented on by Crookes these electrons move with a velocity about one-tenth that of light The stream of electrons is spoken of as "kathode rays"

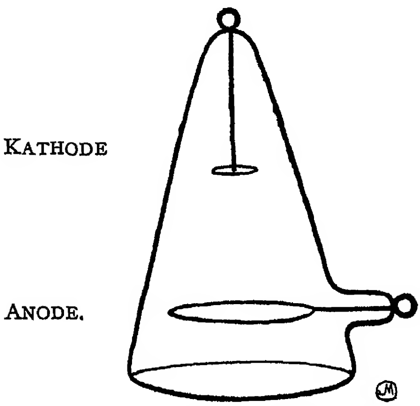


Fig 5 —EARLY PATTERN OF X-RAY TUBE

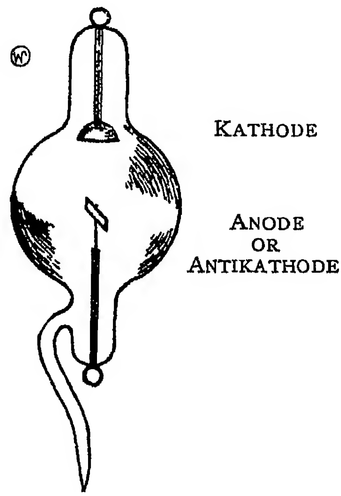


Fig 6 —JACKSON'S ORIGINAL MODEL OF X-RAY TUBE

Lenard, working later with highly exhausted Crookes tubes, shewed that the rays could pass through some substances opaque to ordinary light, could excite fluorescence on suitable substances, and could act on sensitive photographic plates

Roentgen—about the end of 1895—discovered that kathode ray tubes emit other rays capable of exciting a fluorescent screen These he named X rays

X rays are produced by the impingement of the rapidly moving kathode rays on an obstacle in their path. In the earliest tubes, as represented in Fig 5, they were produced by the bombardment of the glass wall by rays proceeding from

the kathode. That consisted of a flat disc of aluminium, whilst the anode was annular in form.

Professor Jackson, of King's College, London, in 1896 made important and essential alterations in design The kathode was by him made of concave form, so as to focus the rays proceeding from it to the centre of the tube This focussing of the kathode rays is assisted by repulsion of the electrons from the glass walls of the tube, which become negatively charged Near the central focal point was introduced a metallic target called the anode or antikathode This target was set at an angle of 45 degrees to the axis of the tube, so as to throw the main part of the X rays to one side of the tube This device rendered the study and employment

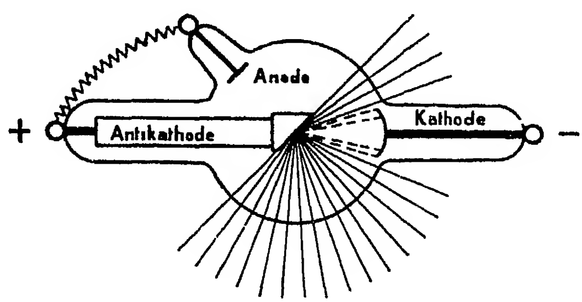


FIG 7.—DIAGRAM OF X-RAY TUBE SHEWING PATHS OF RAYS

of X-ray effects much more precise, since the rays proceed from a definite point or small area of the target

Fig 6 represents the X-ray tube as designed by Jackson, the figure being drawn from an original model

Fig 7 represents diagramatically a form of X-ray gas tube commonly made at the present day, and it is remarkable how slight are the changes that have been made since Jackson's design in 1896 The figure also shews diagramatically the path of the kathode rays converging on the target and the beam of divergent X rays produced by their impact there

The Incandescent-Kathode Tube.

The Coolidge Tube —The important discovery by Professor Richardson that a heated filament emits electrons was in 1913 utilised by Dr Coolidge in the development of a new type of X-ray tube In the gas tube the presence of residual gas is essential for the production of kathode rays The current-

carrying gas provides positively charged atoms, and bombardment of the kathode by these causes the emission of kathode rays If the kathode, however, consists of an electrically heated filament, this directly provides the supply of electrons, so that the action of the gas may be eliminated and the gas may be exhausted from the tube to a much higher degree This gives much greater control over the production of X-radiation, and consequently the production of the incandescent-kathode type of tube marks a great advance in the development of the science of X rays The Coolidge tube will be found illustrated in Fig 29, on page 45, annexed to which is a more detailed description of the tube and its action

The Lilienfeld Tube—Shortly prior to the production of the Coolidge tube in America, a tube of the incandescent-kathode type was produced on the continent by Lilienfeld This tube is little used in this country, but along with the Coolidge tube is noticed more fully in a later chapter (see Fig 41, on page 56)

Electrical Supply.

For the production of X rays of the kind used in radiology, pressures of 50,000 volts to 200,000 volts are essential This may be derived from an ordinary main supply of 100 to 240 volts pressure, the required modification being produced by means of transformers of special construction Those transformers are described and discussed in Chapter IV

Properties of X Rays.

Until about ten years ago much controversy existed regarding the nature of X rays

The discovery that those rays can be reflected and diffracted by crystals settled the controversy, and established beyond doubt that X rays are light rays of extremely short wavelength, for the most part less than the diameter of the atom

For further information regarding the nature of X rays and allied problems in physics, the reader should refer to the work on X rays, by Dr Kaye, of the National Physical Laboratory. There will be found the collected results of physical research on the subject presented in a clear and interesting fashion

Of the physical properties of X rays little need be said here. The property upon which depends their use in medicine as

a diagnostic aid is that of penetrating many substances opaque to ordinary light The degree of penetration varies with the density of the irradiated substance, the penetration being, generally speaking, greater as the density of the substance is less Thus differentiated shadows are cast of the different tissues, and departures from the normal may be detected Bone, being denser than muscular or other soft tissue, is more opaque to the rays, hence it casts a deeper shadow, and alterations in its density, as in necrosis, will influence the shadow cast, while such lesions as fracture will do so more markedly

To the naked eye X rays are not visible, and such reduction of their intensity is not discernible, hence two other properties are brought into requisition—that of rendering fluorescent certain substances such as platino-cyanide of barium and tungstate of calcium, and that of acting upon sensitised photographic plates

The intensity and differentiation of the shadow cast on a fluorescent screen by a certain radiation will depend upon the nature of the body or substance interposed between the screen and the source of the transilluminating rays; and so likewise will depend the image impressed on a photographic plate exposed for a suitable time

The effect of X rays on living tissue is utilised in treatment of various conditions of the skin and of deeper parts, as well as in the treatment of neoplasms before or after surgical operation and in inoperable cases, but for details of such use a special work on radiotherapeutics should be consulted, although the principles underlying all such will be found fully considered in the following chapters.

CHAPTER I

X-RAY CHARACTERISTICS AND THEIR MEASUREMENT

Quality or Hardness—Quantity or Intensity

BEFORE studying in greater detail the various kinds of X-ray tube and their uses, it is necessary to understand the characteristic features of the rays emitted as well as the methods employed in radiology for the measurement of those characteristics

It is a well-known fact that a source of light emits rays covering a fairly wide range of wave-lengths, the intensity increasing continuously with increase in wave-length up to a

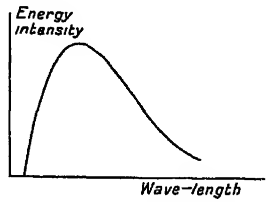


FIG 8—EMISSION OF LIGHT RAYS.

maximum, after which it decreases continuously, as shewn in the rough graph in Fig 8

With a higher temperature of the source the shorter will be the wave-length at which the maximum energy intensity occurs

In emission of X rays from an X-ray tube the energy is distributed amongst the range of wave-lengths in much the same way, although under certain conditions there are superimposed upon the general radiation certain rays of definite wave-length which are characteristic of the metal of which the target is made

The rays of shortest wave-length in the heterogeneous beam of X rays emitted are characteristic for the particular voltage applied to the tube, the higher that voltage is the shorter will be the wave-length of those characteristic rays, and the greater will be the percentage of rays of shorter wave-length present in the beam.

When the applied *voltage is low* the rays are said to be "soft," and when the applied *voltage is high* the rays are said to be "hard," these terms having reference to the penetration Generally speaking, X rays of longer wave-length are relatively easily absorbed by matter, those of shorter wave-length possess a greater power of penetration

It is upon this power of penetration as affected by the varying density of the irradiated substance that the value of X rays in diagnosis depends

Thus "soft" rays will with difficulty penetrate bone, and if exposed to such rays the larger bones of the body will cast very deep shadows On the other hand, "soft" rays will reveal detail of structure in the smaller bones which would be entirely undefined by the more penetrating "hard" rays suitable for viewing denser structures

The only satisfactory way of ascertaining with precision both the quality and quantity of X-radiation emitted from a tube is by means of the X-ray spectrometer, which enables the energy distribution in the X-ray spectrum to be measured This measurement, however, requires the skill of a trained physicist, and is much too slow and elaborate for the radiologist, who requires rather a rapid and easy means of gauging the amount and character of the radiation he is using Recent instruments designed to simplify the application of spectrometer methods bring them more within practical range, but as yet those are experimental Many other methods have been suggested for practical purposes, and several are found in daily use, more or less satisfactorily In considering those methods, illustrations will be found of some of the more general properties of X rays The problem is, however, somewhat analogous to that in light of expressing by some scale the colour of a heterogeneous mixture of various pure spectrum colours, the relative amounts of which may differ in different beams.

Quality or Hardness.

It is generally recognised that of the simpler methods of gauging the quality or hardness of the rays, greatest precision is attained by measuring the voltage across the tube by the *alternate equivalent spark-length* between spheres of a definite diameter.

This procedure may be regarded as satisfactory provided

that the conditions under which comparisions are made do not differ too widely

The fact that the distribution of energy intensity in the X-ray spectrum may vary somewhat with the type of tube used, and with the character of the applied potential (whether continuous or intermittent), renders any simple method such as this liable to error, but the spark-gap method intelligently employed is accepted as sufficient for practical purposes

It furnishes a register easy of measurement and, as a relative index, observation of its constancy or alteration gives in practice most valuable guidance

With all such approximate methods it must be borne in mind that the rays are not homogeneous nor all of the hardness indicated by the measure, but that there is an admixture of

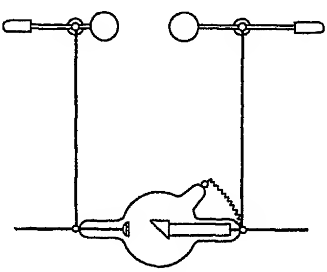


FIG. 9—EQUIVALENT SPARK-GAP

rays of other wave-lengths, consequently a rough average measurement is all that is possible.

Equivalent Spark-gap.—If a spark-gap be arranged in parallel with the X-ray tube, as in Fig 9, it provides an alternative path for the current, which will take that of least resistance. Consequently, by adjusting the width of the gap between the spheres until sparks just fail to pass across it, the length of the equivalent spark-gap may be determined.

Under normal atmospheric conditions (and the variation under abnormal conditions is not practicably appreciable), each spark-length corresponds to a definite maximum voltage across the gap To shew this relation for spheres of definite size a curve may be plotted, or from a table, such as that annexed, the corresponding voltage may be ascertained for any observed equivalent spark-length From such a table a worker, wishing to utilise rays of hardness corresponding to a known voltage,

may see to what alternative spark-gap he must set or adjust his machine to obtain the quality of radiation desired.

Spark-gap Voltages

At 760 mm. pressure and 25° C.

Where any gap is being used outside its recommended limits, the figures are shown in brackets. The blank spaces indicate that the gap is no longer suitable. (Adapted from Kaye's "X rays", Longmans.)

Pressure in Kilovolts		Needle Points		Spheres of Diameter		
Coils and Transformers Peak Value	Transformers R.M.S. Value	cm. gap	in. gap	2·5 cm. cm. gap	5 cm. cm. gap	10 cm. cm. gap
5		(0·42)	(0·17)	(0·13)	(0·15)	(0·15)
10		(0·85)	(0·33)	0·27	0·29	0·30
15		1·30	0·51	0·42	0·44	0·46
20		1·75	0·69	0·58	0·60	0·62
25		2·20	0·87	0·76	0·77	0·78
30	20	2·69	1·06	0·95	0·94	0·95
35	23	3·20	1·26	1·17	1·12	1·12
40	27	3·81	1·50	1·41	1·30	1·29
45	30	4·49	1·77	1·68	1·50	1·47
50	35	5·20	2·05	2·00	1·71	1·65
60	42	6·81	2·68	2·82	2·17	2·02
70	49	8·81	3·47	(4·05)	2·68	2·42
80	57	(11·1)	(4·36)	—	3·26	2·84
90	64	(13·3)	(5·23)	—	3·94	3·28
100	72	(15·5)	(6·10)	—	4·77	3·75
110	78	(17·7)	(6·96)	—	5·79	4·25
120	84	(19·8)	(7·81)	—	(7·07)	4·78
130	90	(22·0)	(8·65)	—	—	5·35
140	98	(24·1)	(9·48)	—	—	5·97
150	105	(26·1)	(10·3)	—	—	6·64
160	113	(28·1)	(11·1)	—	—	7·37
170	120	(30·1)	(11·9)	—	—	8·16
180	126	(32·0)	(12·6)	—	—	9·03
190	133	(33·9)	(13·3)	—	—	10·0
200	140	(35·7)	(14·0)	—	—	11·1
210	147	(37·6)	(14·8)	—	—	12·3
220	154	(39·5)	(15·5)	—	—	13·7
230	161	(41·4)	(16·3)	—	—	15·3
240	169	(43·3)	(17·0)	—	—	17·7
250	176	(45·2)	(17·8)	—	—	(19·5)

For direct use the instrument may be calibrated directly in voltages, as in the type illustrated in Fig. 10.

It should be clearly understood that the relationship between spark-gap and voltage depends upon the size of sphere used, and is totally different if needle-points or a point and plane are used instead of spheres, as may be seen from the foregoing table. If a point and plane be used, the gap for a given voltage will depend also upon the direction of the current. For those, and other, reasons it is important that some standard form of gap should be recognised. For certain purposes a point-gap has a possible advantage, in that the corresponding readings show larger intervals between adjacent

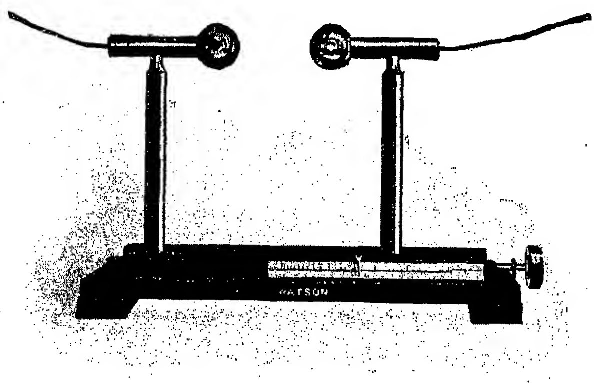


Fig. 10.—SPHERE-GAP VOLTMETER.

voltages, but for ordinary purposes the sphere-gap is admittedly the preferable form.

To prevent perforation, when using a hard tube it is well to leave the spark-gap only a little wider than the working distance of the tube. Otherwise, if the tube becomes too hard, there is no alternative path provided, and the current, if "pushed," will pass between the electrodes of the tube through the air outside, or seek a shorter path from the kathode to the outside by piercing the glass. This "perforation" will destroy the vacuum, thereby rendering the tube useless, and repair is very difficult. If perforation occur, the tube will be seen to change rapidly and violet light to appear, while production of X rays entirely ceases.

Other methods may be employed to obtain a more or less rough estimate of the penetrative power of X rays.

(*a*) By observing the **shadow cast on a fluorescent screen by a hand** interposed between that and the X-ray tube, earlier workers, to their later regret, were accustomed to get some idea of the nature of the rays emitted This is at the best but a rough, relative test, and is not to be recommended, as such repeated exposure of the operator's hand may lead to a serious dermatitis It is mentioned here, indeed, mainly to introduce the caution that it *should not be done*

(*b*) Instruments are made on the same principle as the tintometer apparatus for estimating the hæmoglobin of the blood, and are known as **radiometers** or **penetrometers.**

In these the power of the rays to penetrate a metal of uniform density, but varying thickness, is observed and com-

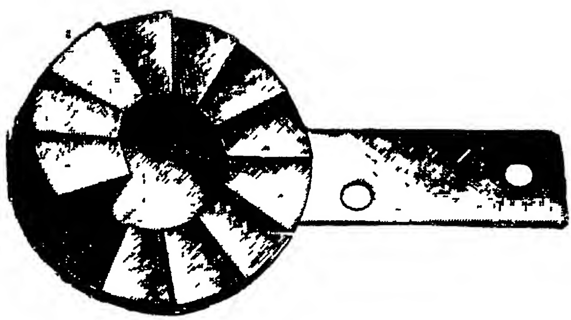


Fig 11 —Benoist's Radiometer

pared with a standard The instrument of **Benoist** is one of the earliest, and consists of a thin central disc of silver, surrounded by a flat ring of aluminium graded by steps in thickness from 1 to 12 millimetres, as seen in Fig 11.

Silver was found by Benoist to be almost equally transparent to hard and soft rays, and was used by him as a suitable standard, the transparency of aluminium varies considerably with the quality of the rays and thickness of the metal interposed

For use the instrument is placed so as to intercept the rays from a tube, the shadow cast on a fluorescent screen or photographic plate is observed, and the sector or step which produces a shadow of density similar to that of the standard disc in the centre is noted The sectors being numbered according to their thickness, the higher numbers will correspond to harder tubes

In Fig. 12 are represented a series of appearances of a radiometer as viewed on a fluorescent screen irradiated by X rays ranging in penetration from very hard to very soft; the appearances would be similar on a print from a radiogram, but would be reversed on the radiogram itself, which is a negative, as explained in a later chapter. In the top right-hand picture of the series the rays in use were about 12 Benoist in hardness, whilst in the bottom right-hand picture the rays were softer than No. 1 (even the wrapper of the film having been sufficient to protect the film from the effect of exposure), so

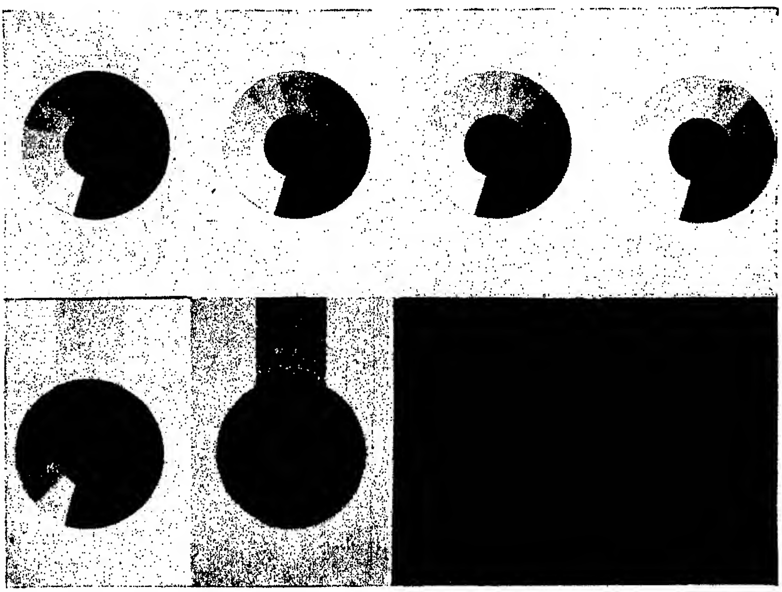


Fig. 12.—"Positive" Radiometer Appearances.

that the contrast is well brought out, although the intervening grades of comparison are somewhat lost in the process of reproduction.

The discharge potential across a tube may be roughly reckoned as being 6,000 to 10,000 times the Benoist reading of the X rays emitted.

On a similar principle several modifications of Benoist's penetrometer have been designed.

In the **Wehnelt Penetrometer**, shewn in Fig. 13, a wedge-shaped strip of aluminium is substituted for the series of steps, and is mounted parallel to a silver strip of uniform thickness.

By comparing the luminosity produced on a fluorescent screen by the rays transmitted through the two adjoining strips, the thickness of aluminium corresponding with the silver standard is observed, and the hardness of the tube in use is denoted by the number corresponding to that thickness In the simple form shewn in Fig 13 the two strips may also be laid on a photographic plate during exposure, and will leave on the plate a permanent record of the hardness of the tube

Walter's instrument consists essentially of a sheet of lead mounted behind a fluorescent screen, the lead having in it eight circular holes covered by sheet platinum of varying thickness With a tube in action a greater or lesser number of holes show up on the screen, according to the hardness of the tube

Certain standards have been suggested for comparison of observations, but none is generally accepted, whilst the scales

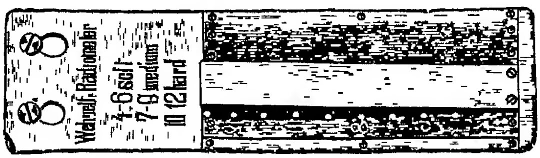


Fig. 13.—Wehnelt Penetrometer

of the penetrometers in use are quite arbitrary and have no reference to the usual physical standards

In the different instruments, also, the scales have different values, so that one must always mention the particular type employed in any observations

A table of equivalent values is appended to this section (on page 20)

(*c*) The **Bauer Radio-Qualimeter** (Fig 14) is a high potential static voltmeter which, like the alternative spark-gap, is useful and convenient to check the action of any tube during excitation under fixed conditions, although useless as a standard of comparison

The instrument consists of two pairs of metal plates placed at a certain distance from one another, *one* pair being fixed, the *other* pivoted and carrying the needle

The instrument is connected, by as short a connection as possible, to *one* terminal of the coil or of the tube. The plates become charged with electricity of like sign and repulsion takes place between them, causing the pivoted plates to rotate on their axis

The amount of this repulsion depends upon the potential of the terminal to which it is attached, and is indicated by the deflection of a pointer over a suitably divided scale

This scale is constructed so as to indicate that the rays produced are of such quality or hardness as to be absorbed by a certain number of sheets of lead, each $\frac{1}{10}$th millimetre in thickness This standard is seen to be in reality, however, quite arbitrary when it is recognised that with the same tube in use the reading will vary with the type of transformer used, with the frequency of interruption, and other variable data

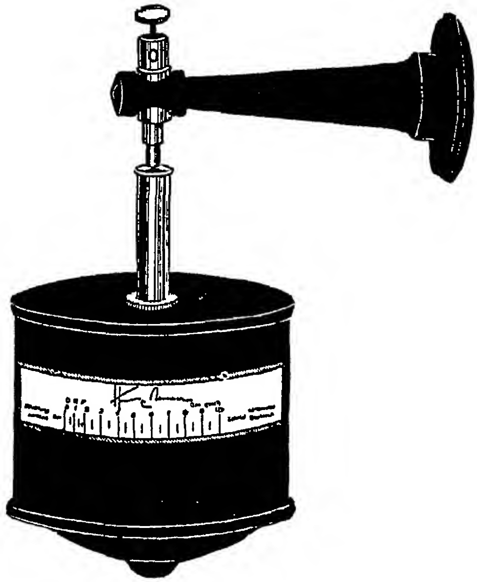


Fig 14—Bauer Radio-Qualimeter.

If a preliminary estimate be made of the quality of the rays emitted, and the same tube be continued in action with the same coil, interrupter and frequency, the scale is easily translated into a real index of hardness

The relative movement of the needle then affords an easily observed index of change in quality of radiation.

The instrument must be well insulated, and is usually swung from a bracket, so as to hang always in a vertical position

It should be placed at a distance from any objects likely to earth it or influence its action by changing its potential

However placed, since the instrument is unipolar, its indications will depend somewhat upon its position relative to surrounding bodies, and consequently each installation requires standardisation

Scales.—The corresponding hardness-numbers of the other scales are all much the same as Benoist's, except those of Wehnelt, which are 50 per cent higher for the same quality of rays The following table shows roughly the equivalence of the scales —

		SOFT			MEDIUM				HARD		
Benoist, scale		1	2	3	4	5	6	7	8	9	10
Wehnelt, scale		1·5	3	4 5	6	7 5	9	10 5	12	13 5	15
Walter, scale		1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	—	—
Bauer, scale		1	2	3	4	5	6	7	8	9	10
Alternative spark-gap, needle-points	with ins	1	2	3	4	5	6	7	8	9	10
Alternative spark-gap, 5 cm spheres	with cms	0 9	1 5	2 2	3 0	3·8	4 7	5 8	7 1	9 4	—
Alternative spark-gap, 10 cm spheres	with cms	0 9	1·5	2 1	2 7	3 2	3 7	4 3	4 9	5 6	6 5

Quantity or Intensity of X Rays.

The quantity of rays produced must be taken into consideration as well as the quality, and again, on account of the heterogeneous character of the rays and the many factors which may vary during an exposure, it is extremely difficult to get a satisfactory measure of the X-radiation actually in use.

By noting the average current passing through a tube in action, or by noting the actual effect, chemical or otherwise, of the rays produced, the quantity of X rays may be roughly judged and their probable effect calculated, although none of the present every-day methods of measuring the quantity of radiation or its effect are wholly satisfactory.

As already pointed out, the only satisfactory means of measurement is by use of an X-ray spectrometer, which separates the beam of rays into its constituent wave-lengths, and measures the intensity distribution amongst those wave-lengths, the latter purpose being achieved by utilising the production of gaseous ionisation by the rays

By watching the register of a **milliammeter** inserted in the

tube circuit, which measures the average electric current flowing through the tube, the production of rays may *to some extent* be estimated, and the time of exposure for any desired effect judged.

For the readings of a milliammeter to be of value, however, it is essential that the characteristics of the source of current supply remain constant

This is frequently not the case, especially with an induction coil as the source of supply

It has recently been shewn (by Dr Owen and Miss Bowes), by using an ionisation method of measuring the intensity, that for a constant potential across the tube, as indicated by a sphere-gap, the intensity does not increase continuously with increasing milliamperage

It rises rapidly at first, and subsequently becomes practically constant, however much the milliamperage may be increased This result was obtained with a Coolidge tube driven by an induction coil, and the discrepancy is probably not so marked with a gas tube, but it will be seen that considerable reserve is necessary in using the milliamperage as a measure of X-ray intensity. To the person familiar with the behaviour of any particular outfit, however, the relative indications of the milliammeter may be of considerable use

To secure a true indication of the current, it is essential that the current passing through the milliammeter should be strictly unidirectional If inverse current be present, as well as direct, the reading will indicate only the difference between the two opposite currents, and will be quite misleading Methods should be adopted, therefore, as explained later, to cut off all such inverse currents from the circuit

In considering an exposure with rays of known quality, the factors of *time* and *distance* have to be taken into consideration

The same current, under conditions constant as far as the tube and character of the electric supply are concerned, will produce an effect which varies *directly* with the *time* during which the exposure continues, and, like light, *inversely* as the square of the *distance* between the antikathode of the tube and the object exposed

Hence it became common practice to express exposure times in milliampere seconds, assuming that so long as that product remained constant either constituent factor could be varied without affecting the result As explained above, however the

output of X rays is not strictly proportional to the current passing through the tube

Tables of exposure expressed in milliampere seconds are, therefore, only useful within a small range on either side of a given milliamperage employed in the empirical construction of the table After reference to such a table for rough guidance, each radiographer should construct, by trial with his own outfit and with currents commonly employed in it, a table for the use of that outfit

Times of exposure are further considered in the chapter on "Photography"

All other methods for measuring the intensity of X-radiation depend upon one or other of the properties of the rays heating, ionising, fluorescing, photographic or chemical. As already described, X rays vary much in quality, and all beams of rays are heterogeneous In most of the methods of measurement the index is not by any means independent of the quality of the rays, since soft rays, *being more readily absorbed*, produce more effect relatively than hard Thus, viewed from an energy standpoint the records would be very misleading, but from a therapeutic or photographic standpoint this does not affect the practical use of the methods, since the standards set are purely empirical and the effects measured may be considered as closely related to the effects it is desired to control

Ionisation Methods.—As already mentioned, for accurate results intensity is measured by observing the ionisation effects of the X rays

X rays have the property of "ionising" the air through which they pass, and thus make it a conductor of electricity, the effect being proportional to the intensity of the radiation

The degree of the effect may be measured by noting the rate of discharge of a previously charged electroscope, and on this principle several instruments have been designed. As yet those must be considered too complicated and delicate for everyday practice, but as the necessity grows for more accurate estimate of dosage in deep therapy, the necessary time and care may be justified and simplifications will doubtless be made The principle of the action may be understood by reference to Fig 15, which represents diagramatically such a piece of apparatus, known as the **Ionometer.** The main part of the apparatus consists of an *aluminium leaf electroscope* (CA), in which the movable leaf (*a*) when charged is repelled from the

vertical and its movement read on a scale (G) The electroscope is enclosed in a thick lead shield (P), so that direct radiation has no effect upon it From the charging knob at the top of the leaf stem passes an electrical connection (*r*) to a metal conductor (*f*), which, at its other end, is electrically connected to a graphite stem (*tg*) enclosed in a small hollow cylinder (CI) of the same material The conductor and central graphite stem are most carefully insulated from the containing sheath (R) and cylinder (CI), and the latter is known as the *ionisation chamber*

When this ionisation chamber is exposed to the action of rays from an X-ray tube (*Amp*, in Fig 15), the contained air

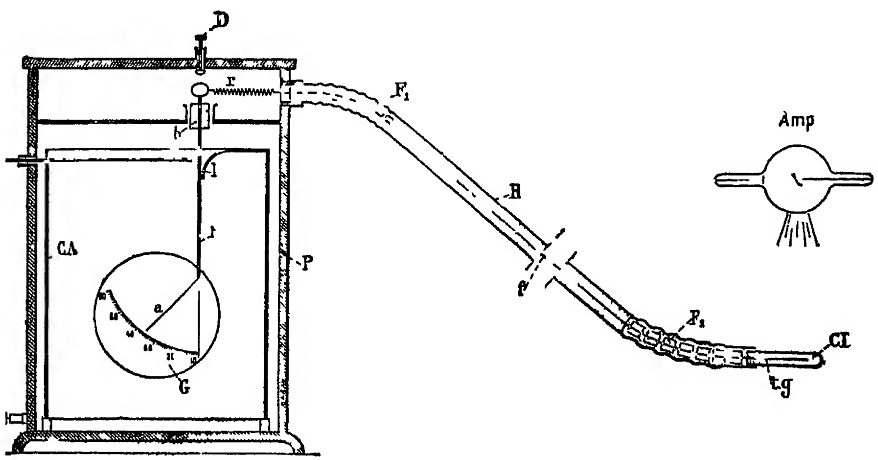


Fig 15—The Radiological Ionometer

becomes ionised, and the charge from the central stem (in electrical continuity with electroscope leaves) escapes through the air, the rate of discharge being indicated by the rate of fall of the leaf (*a*) in the electroscope This rate of discharge, as already mentioned, is directly proportional to the quantity of radiation falling upon the ionisation chamber and forms, therefore, a comparative measure of the intensity of radiation from the source in question.

Various filters may be interposed between the X-ray tube and the ionisation chamber, and the rate of discharge compared with that noted when the chamber was freely exposed, the distance being, of course, kept constant By such means an analysis of the quality of the rays dealt with may be made, but

the more practical use is in comparing superficial therapeutic doses with doses at various depths, equivalent filters of metal, water and other substances being interposed, or the ionisation chamber actually placed at measured depths in the tissues during therapeutic (or experimental) exposure

Many details not mentioned require attention in using such delicate apparatus, but the above notes should serve as an introduction to its use, which is likely (possibly in amended form) to become much more general in the near future

In practice most workers at present depend upon instruments based upon the photographic or chemical effects of the rays—principally the latter

As aids to "dosage" the following methods have been suggested —

(*a*) The discolouring of various alkaline salts (Holzknecht, 1902).

(*b*) The liberation of iodine from a 2 per cent solution of iodoform in chloroform (Freund, 1904, Bordier and Galimard, 1906)

(*c*) The darkening of a photographic emulsion (Kienbœck).

(*d*) The precipitation of calomel from a mixture of mercuric chloride and ammonium oxalate solutions (Schwarz, 1907)

(*e*) Change of colour of pastilles of compressed barium platino-cyanide (Sabouraud-Noiré and Bordier)

Methods (*a*) and (*b*) have not held the field for practical use.

On method (*c*) is based **Kienbœcks Quantimeter,** which employs strips of silver bromide paper exposed on the skin of the patient under treatment.

The method is sensitive and accurate, and furnishes a permanent record which may be preserved along with notes of the treatment The strips, however, require to be developed before the record can be read from them, and the disadvantage of this renders the method inconvenient in practice The total value of several exposures made at different times may be registered by exposing the same strip each time

Method (*d*) is utilised in a **Calomel Radiometer,** which measures the opacity produced by precipitation in the solution against a scale of diaphanous glass of graduated opacity

Method (*e*) has found most favour with medical men, and

with respect to that method the use of such intensity-measures may be explained.

Pastilles are exposed to the rays during the actual exposure, and by change in colour indicate the quantity of radiation and the probable therapeutic effect. Consisting of platino-cyanide of barium, thickly coated on small discs of paper, usually 5 mm. in diameter, the pastilles on exposure to X rays alter in colour from apple green through yellow to red-brown. The change is proportional to the cumulative effect of the exposure. Thus, by comparison with a standard tint the operator can determine from the pastille when the desired degree of exposure has been reached.

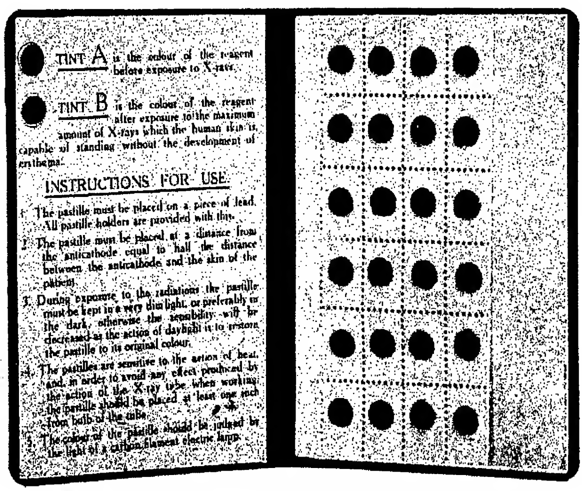


Fig. 16.—Book of Sensitive Pastilles.

Where a maximum therapeutic effect is desired at one exposure, as for epilation in treatment of ringworm, it is pre-eminently important that the degree of exposure should be carefully measured, for the margin of safety between epilation and a serious dermatitis is narrow.

The use of the pastille as a measure of dosage has been the subject of a great deal of criticism. The question has been investigated at the National Physical Laboratory (Owen and Bowes, J.R.S., July, 1921), where it has been shewn that the indication of the pastille agrees accurately with the ionisation method.

In the latter method it is found that the product of the time of exposure (or dose) and the ionisation per minute is the same,

however the current through the tube and other factors may vary The relationship is strictly true if the voltage is constant and approximately true even when the voltage varies Since pastille indications are found to correspond with those given by ionisation, it may fairly be assumed that the same relations hold true in the use of pastilles, and, carefully used, the pastille method is thus definitely established as a reliable guide to X-ray exposure

In treatment the *full dose* of X-radiation is considered as the dose which will cause a slight erythema to appear within

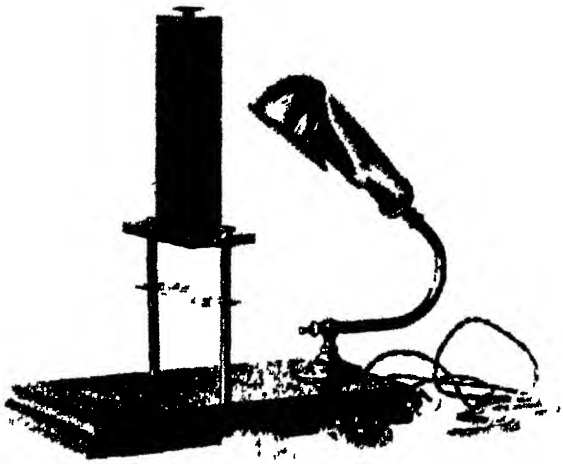


Fig 17.—Radio Tintometer

fifteen to twenty-one days, the skin being exposed to the direct action of the rays without intervention of any filtering medium, and the X-ray tube being of medium hardness (about 6 Benoist)

Four-fifths of this erythema or full dose (the latter term being preferable) will cause the hairs to fall out

This is a critical dose, being that requisite for treatment of ringworm.

Sabouraud gives but one tint for comparison of the change produced in the pastilles known by his name This tint, called "Teinte B," corresponds to the dose necessary for epilation, that is, four-fifths of a "full dose."

Holzknecht employed a method of comparing two pastilles that allowed measurement of exposures short of the full epilation dose. This is done by moving the unexposed pastille under a celluloid band of graduated red-brown colour till it appears of the same tint as the exposed pastille. The scale divides the dose into five parts.

Kienbœck divides the dose on his scale into ten equal parts, each of which he calls X.

Thus,	"Teinte B"	on	Sabouraud scale
corresponds with	5 H	,,	Holzknecht ,,
,, ,,	10 X	,,	Kienbœck ,,
,, ,,	10	,,	Ionto Quantimeter index
,, ,,	3·5		Kaloms on Schwarz scale.

For greater convenience and accuracy in matching the tint of exposed pastilles with standard tints various arrangements have been suggested.

A definite and constant light should always be employed, the standard tints having been prepared for that special illumination. Thus, daylight, at best variable, should never be relied upon for such observations. Screened daylight has been suggested, but one of the various *tintometers* devised for use with a standard artificial light should preferably be used for precision.

Fig. 17 shews a simple arrangement of the kind, in which the standard tints, in the form of permanent tinted glasses, are mounted in series around a circular disc, by the revolution of which any tint may be brought under observation for comparison alongside the exposed pastille.

CHAPTER II

X-RAY TUBES

Gas-Tubes—Incandescent-Kathode Tubes—Valve-Tubes

X-RAY tubes used in medical radiology are, broadly speaking, of two types—gas tubes and incandescent-kathode tubes The relative merits of the two types of tube have been much discussed in recent years, and preference depends largely upon the particular purpose for which the tube is required and upon the particular circumstances of its use

For purposes of research the incandescent-kathode type is undoubtedly preferable, since with this type the condition of a tube may be kept constant over a long period, and may be accurately reproduced on a future occasion as desired for further investigation. Both of those points are of immense importance in research work on X rays and are very hard to attain with a gas tube

For ordinary radiographic use, however, the necessity of auxiliary apparatus for heating the filament of the incandescent-kathode tube (as mentioned on page 48, and further described on page 54) may be considered a drawback, and it is noted that under similar conditions of current and applied potential this type of tube is less efficient than the gas tube in the production of X rays, a point that might be of importance where economy of current is a valid consideration

Many radiographers are of opinion that finer radiographs are obtainable with gas tubes, but this seems in most cases to depend upon the sharpness of focus. Incandescent-kathode tubes are frequently constructed to carry heavy currents for short periods, and with this in view a sharp focus of the kathode rays on the target is not possible for fear of fusing the target The X rays emitted take origin therefore from a broader area of the target, and the resultant radiograms are correspondingly blurred in outline and detail

Fine-focus tubes may be obtained of either type, but this places a limitation upon the amount of current to be safely used and cancels the advantage in that respect of the

incandescent-kathode tube. Under similar conditions and with equal care in selection of a suitable tube, it may safely be said that there is little to choose between the results obtainable, and, as in this country and in the army service during the late war, the choice will be decided rather by factors of convenience in the production of those results.

During the war very efficient gas tubes were produced by British manufacturers, who were prevented by patent rights and by certain inherent difficulties in the manufacturing plant from producing incandescent-kathode tubes. Moreover, very few of the many X-ray outfits in use in war hospitals at home and in the field were suitable for the latter type of tube, so that the great bulk of X-ray work during the war was carried out with the earlier (gas) type of tube, and finer results could hardly be desired than many of the radiograms so produced.

Questions of initial cost and cost per case must be taken into account, and, if breakages be allowed for in equal numbers, the balance on this score is with the gas tube.

Those various factors must be balanced by the radiologist for each particular set of circumstances; a decision of universal preference is not yet attainable, nor is it likely to be.

The Gas Tube

The historical development and principal features of the gas tube have already been briefly described in the introductory chapter. The essential parts, namely, kathode, antikathode, and anode are contained in an evacuated bulb, usually of 7 or 8 in. diameter, as shewn diagramatically in Fig. 7, and also in more detail in the annexed diagram, Fig. 18.

The disposition of those metal electrodes of the tube is important. Thus, the placing of the kathode in the constricted stem of the bulb makes it more difficult for discharge to pass in the wrong direction across the tube, and thus tends to eliminate inverse current, a disturbing factor discussed later (page 34).

The antikathode is placed centrally in the tube to facilitate the focusing of the kathode rays on its surface, and it is inclined so that the X rays may be emitted in a convenient direction. On account of its nearness to the kathode, the antikathode thus placed cannot act satisfactorily as anode for the current discharge,

so an additional anode is placed behind it and the two are electrically connected externally

The **metal parts** have been modified in various ways to avoid disintegration and damage from overheating Since the main cost of a tube is in the labour of manufacture—and this is

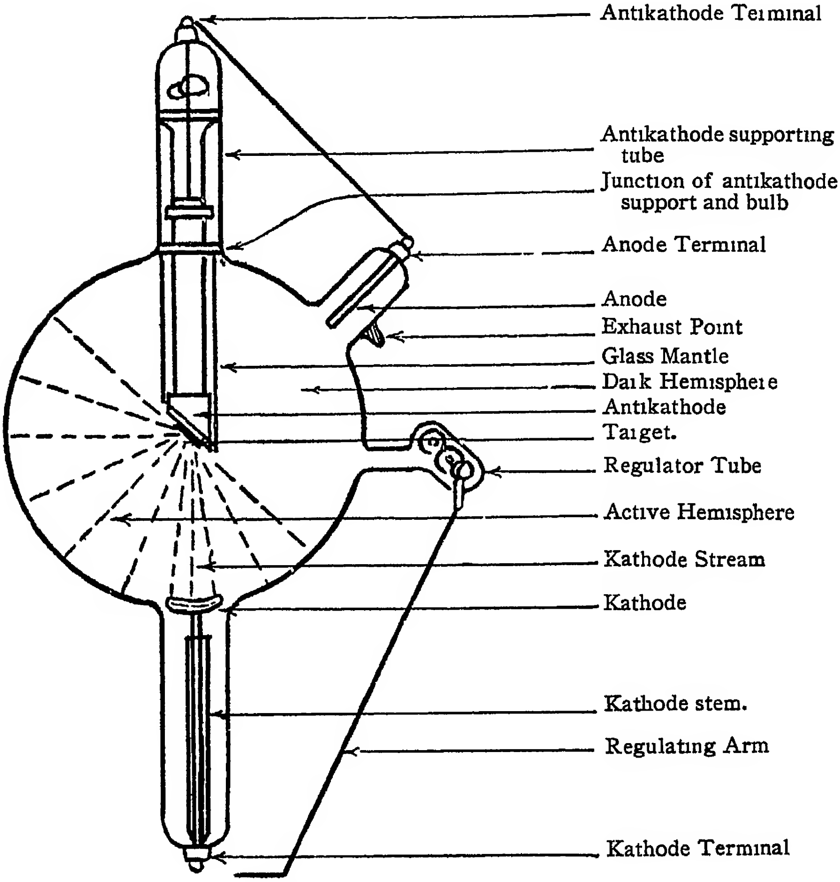


Fig 18.—X-RAY TUBE DIAGRAM

the same whatever material be employed—it is obvious that the best suitable material should be insisted upon in all tubes, however their design or construction may be modified to lessen their price The **purity** of metals employed is of prime importance, especially in the case of the **kathode** and its supporting stem, for which **aluminium** has proved to be pre-eminently suitable

Much of the value of a tube depends upon the construction

of the **antikathode**, since the quality of the resultant radiation, particularly for the higher potentials, depends largely upon the material opposed to the kathode rays Probably in no case are the kathode rays all stopped by their first impact on the surface atoms of the target, but some rays penetrate to deeper atoms before being stopped and giving origin to the resultant X rays. Thus radiations are produced, as it were, from successive layers of atoms, and this would seem to explain the origin from one tube of a collection of rays of differing qualities Those rays produced by the stoppage of kathode rays at the first row of atoms are of the highest degree of penetration

The suitability of any metal for an antikathode depends further upon its melting point and other physical properties, whilst a few, otherwise suitable, are of prohibitive scarcity and price

Among the metals commonly employed are osmium, iridium, tungsten, tantalum, and platinum Of these **platinum** possesses the highest radiation value, and the heavy antikathodes of pure platinum employed in some tubes give beautiful effects It has, however, a relatively low melting point, and is apt to sputter badly. This has led to the wide adoption of targets made of **tungsten,** familiar through extensive employment in electric lamps This metal, compared with platinum, has a higher melting point, sputters less, and has but slightly inferior radiation value.

Iridium, osmium, and **rhodium** behave well as antikathode metals, but their price is prohibitive for ordinary purposes.

During the process of exhaustion of an X-ray bulb, it is essential not only to remove the free gas within the space bounded by the walls of the bulb, but also to remove the gas on the surfaces, and within the pores, of the glass and metal parts This is done by heating the bulb during the pumping process and by passing an electric discharge through the bulb at the same time

If the gas were not thus liberated by passage of a discharge during the process of exhaustion, it would be liberated as soon as the tube was brought into use and would cause the pressure in the tube to rise to such an extent as to check the production of X rays

In most tubes, despite the above procedure, small amounts of gas continue to be released while the tube is in use, but this is more than compensated for by another process which

accompanies the discharge, namely, absorption of the gas by the glass walls of the tube This absorption effect is permanent, the gas so absorbed is not released by subsequent discharges, and gradually the whole of the residual gas becomes used up, so that the tube can no longer function unless some means of reintroducing gas be provided

All modern tubes (as described later, on page 36) are therefore fitted with some form of gas-regulating device, and by careful use of this it is possible to increase or reduce the gas pressure in a tube at will This is of considerable importance in practice, as the hardness, or power of penetration, of the rays emitted by a tube depends upon the gas pressure. If this pressure is relatively *high* the rays are *soft*, whilst if the pressure is *low* the rays are *hard*

In regular use a progressive change takes place in the condition of a tube, due to the *fall in pressure* produced by the absorption noted above, and the rays emitted become progressively *harder* unless the tendency is checked by use of a gas-regulating device

During a single operation, on the other hand, the tendency is towards a progressive *softening*, due to liberation of gas from the antikathode as it becomes heated

If a tube be overdriven, particularly a new tube, which may not have been well "run" during exhaustion, the heating of the antikathode may cause such an evolution of gas as to reduce the equivalent spark-gap practically to zero, and the tube may not recover

Special care should therefore be exercised when a new tube is in use In operating *any* tube, its condition should be observed periodically by approaching the discharging points of the coil or noting the reading of the milliamperemeter If softening of the tube be indicated by a marked shortening of the alternative spark-gap, or rise in the reading of the milliamperemeter, care must be observed that the tube does not receive injury, or the patient be exposed to risk of over-effect. In such event it will be well to decrease the amount of current employed or to give the tube time to cool

The condition of a tube may often be gauged by observing the fluorescence of the glass walls

This normally occurs on that portion of the tube irradiated by the X rays, but is due to kathode rays reflected from the antikathode When a tube is working steadily and satisfactorily,

he intensity of fluorescence remains constant and its extent is clearly defined

Flickering and altered distribution of fluorescence indicate adverse conditions

In use the antikathode should never be allowed to get hotter than indicated by a cherry-red colour, unless softening of the tube is desired for special photographic effects, as will be described later

These and similar points have all to be taken into account in the manufacture of gas tubes, and tubes are made of varying condition according to the purpose they are to serve. It is well, therefore, in purchasing tubes to let the maker have some idea of their intended use, when he will be able to select appropriate tubes accordingly In the catalogues of British tube makers such points will be found discussed in a most interesting and helpful fashion

Sharpness of Focus.

If the kathode rays were focussed to an actual point on the antikathode the metal would readily become fused by the heat Therefore in practice the target, made of platinum or tungsten, is placed a little to one side axially of the focal point, and the X rays originate from a small circular area measuring between $\frac{1}{16}$ and $\frac{1}{4}$ in in diameter To permit of a nearer approach to the true focus, combined with prolonged use, it has been suggested to make the target of osmium or iridium on account of their greater hardness and infusibility, but the expense and trouble in working of those metals are incommensurate with the advantage to be gained by their use This point is further discussed later (p 40).

The focal area on the target is usually indicated by a slight roughening of the metal, the test-running by the maker being sufficient to produce this effect, and it should be looked to in selecting a tube If larger than $\frac{1}{8}$ in in diameter, there will be lack of definition in shadows cast by the tube

A number of interesting devices have been used for testing the sharpness of focus of an X-ray tube One method, applied very successfully to the incandescent-kathode tube, consists in radiographing the actual area of origin of the X rays by means of a pin-hole camera

Another successful method gauges the sharpness of focus by

the definition of outline in radiograms of a piece of fine gauze, or of parallel wires at a fixed distance apart, the distances of those objects from the photographic plate and from the focal spot of the tube respectively being standardised

After exhaustive experiments at the War Office X-ray Laboratory by the physicists working there during the war, a method employing parallel wires was instituted as the most accurate *simple* method of classifying tubes according to sharpness of focus

With the tube placed at a fixed distance of 50 cm above a sensitive plate, three successive exposures of strips of that plate were made, whilst two fine needles, parallel to each other and set 2 mm apart, were interposed between tube and plate at distances above the latter of 5, 10 and 15 cm for the respective exposures

If the intervening space between the needles is definitely represented on the plate when exposed with the needles at 15 cm distance, the tube may be reckoned of *fine* focus, if not at 15 cm but at 10 cm, of *medium* focus, if not at 15 or 10 but at 5 cm, of *broad* focus If the definition of the space be obliterated by cross radiation, even at the 5 cm setting, the tube may be reckoned as of no value for radiography and should only be used, if at all, for treatment

Inverse Currents.

The formation and prevention of **inverse currents** are discussed later, but the matter is referred to now because of the injurious effect of such current upon gas tubes Inverse current is produced by most high-tension machines, and may be of sufficient voltage to pass through an X-ray tube as a discharge

Its presence may be noted in the action of the tube, since it produces a flickering of the luminous discharge, specially noticeable in the hemisphere which is normally dark

Inverse current causes what is termed "kathodic sputtering", that is, from the platinum antikathode (for the time acting as kathode) are torn fine particles which, through the action of the discharge, absorb or occlude molecules of the rarefied contents of the tube and thus increase the degree of vacuum.

Due also to this action the fluorescent hemisphere of a tube undergoes progressive *blackening* on its inner surface by deposit

of finely disintegrated metallic particles, in contrast with the violet tint due to chemical change produced in the glass during normal use

Besides accelerating absorption of the residual gas this deposit tends to cause the discharge to spark irregularly along the walls of the tube instead of through the gas, and, acting as a filter, it arrests the softest X rays in their passage from the antikathode

The blackening is mainly due to the "sputtering" of the antikathode, as described above, but also in slighter degree to similar disintegration of the kathode during the direct phase and to volatilisation of the antikathode at high temperature under reduced pressure

To obviate disintegration during correct operation of a tube, the kathode is generally made of aluminium, which metal is found to resist such action more than any other tried

Where an additional electrode is set in a tube to act as anode, this also is made of aluminium and serves to modify the deleterious effect of inverse current

Seasoning of Tubes.

Carefully used tubes become "**seasoned**" to stand stronger currents or longer exposures with less liability to excessive change New tubes should normally be used at first only with moderate currents for short periods, until they become, as it were, "trained" to do harder work After being seasoned by such treatment, tubes can stand prolonged exposures, or exposures with heavy currents, without liberating an excessive amount of gas and without the consequent alteration in the quality of the rays emitted The current which, passing through a certain tube, liberates just as much gas as is being occluded in the glass walls of the tube and no more, will maintain the vacuum practically constant, and may be well termed the "normal" current for that tube.

To season a new tube, it should be used at first for short exposures on subjects requiring rays of low degree of penetration (*i e*, soft rays), such as radiograms of hands, etc.; then, gradually, it may be used for longer exposures, and for subjects requiring higher degrees of penetration, the condition of the tube whilst in operation being carefully noted meanwhile.

Some tubes are so treated in the final stages of manufacture,

and the necessity for this preliminary seasoning is further obviated by recent improvements in vacuum regulators, but all new tubes should be "nursed" carefully until their condition is known and established.

In certain recent vacuum regulators the store of available gas is so large that the action of the tube need not depend upon the amount of residual gas in the bulb and parts of the tube Such tubes are issued by the makers in rather a hard condition, and the regulator is utilised at once, and as required, to produce the desired condition for any exposure

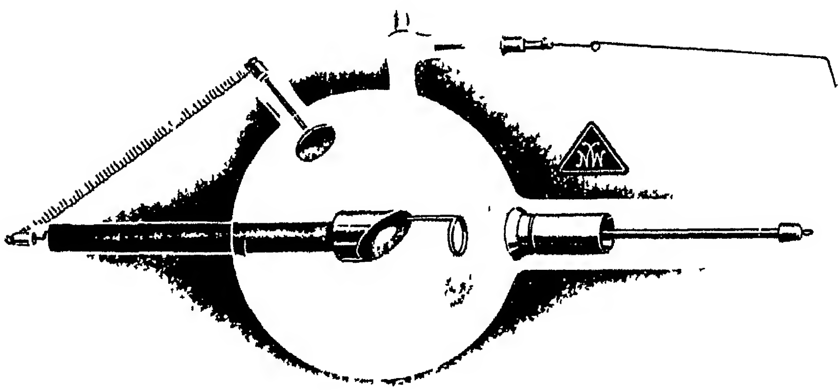


Fig 19—X-ray Tube with Chemical Vacuum Regulator

A milliamperemeter in a tube circuit will indicate any change in the vacuum of the tube If the reading on this tends to rise, softening of the tube is indicated and the current should be reduced, or the rate of interruption lowered, so as to obviate further change

If the reading falls the tube is becoming harder and the current should correspondingly be increased, or the regulator brought into use.

Vacuum Regulation.

A vacuum regulator of some kind is added to all modern tubes Such an addition is an economy, since it counteracts the hardening effect of continued use and thereby prolongs the period of usefulness of the tube.

These regulators, when brought into action, give off or

transmit gas, and the degree of vacuum is correspondingly reduced. Many are set in action by heat, produced either by electric discharge or by direct application of a flame to the regulator

(*a*) A small **side-tube containing a chemical** (such as sodium bicarbonate), which **gives off gas** when heated, may be attached in construction to the X-ray tube, as shewn in Fig 19

(*b*) **A side-tube with some substance** with a large adsorbent surface, such as glass-wool, mica discs, asbestos, or spongy metal, may be similarly connected to the main tube, as shewn in Fig 20 The capillary substance is usually arranged at one

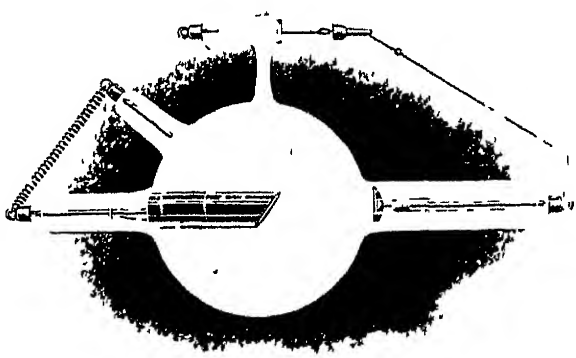


Fig. 20—X-Ray Tube with (Automatic) Asbestos Vacuum Regulator

end of the side-tube, and is traversed or surrounded by a platinum electrode, to which, when put in circuit, sparks may discharge from an electrode in the form of an aluminium disc at the kathode end of the tube By such discharge heat is generated, and the gas adsorbed on the surface of the substance (chiefly CO_2 and water vapour) is therefore caused to be expelled into the vacuum of the larger tube.

Automatic action of such regulators as the above may be attained by affixing to one or each electrode one end of a stiff wire, and arranging the other end of this wire at a suitable distance from the adjacent electrode of the X-ray tube, as shewn in Fig. 19 and in Fig. 20. Then, when the tube becomes of a certain degree of hardness, thereby offering greater resistance to discharge than is desired, sparks will pass automatically from

the electrode to the wire, and thence current will traverse the side-tube From the capillary substance in the side-tube gas (as described above) will be liberated, till by its presence the vacuum of the main tube is reduced to the point at which discharge takes place through it in preference to jumping the arranged air-gap between the electrode and the side-tube wire This practice may be dangerous with a heavy discharge, and it is apt to be somewhat disconcerting to a patient undergoing exposure. It is therefore preferable in all cases to regulate properly a seasoned tube before use

Regulating tubes of the above kind form a very convenient arrangement if carefully used, but the utility of all such regulators depending upon a pre-existent supply of occluded

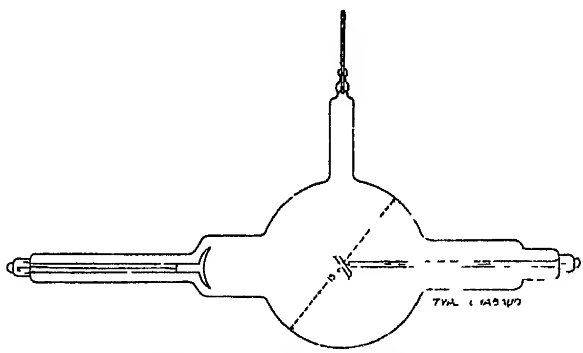


Fig 21.—X-RAY TUBE WITH OSMO-REGULATOR

gases is limited, since after some time all the available gas will be expelled from the capillary spaces, and there is no means of renewing the supply. Short of opening the tube and renewing the material, the regulator thus ceases to be of further service The makers of recent asbestos tissue regulators claim that the supply of gas contained is "practically inexhaustible." This is naturally a relative term, but certainly the range of usefulness is very much extended by recent improvements

(*c*) **Osmo-regulators** do not depend upon any such limited supply, and are therefore preferred by some workers for tubes in continuous working These regulators depend upon the property of certain metals becoming, when heated, permeable to hydrogen, the property of so-called selective "osmosis"

A slender, thin-walled tube of one of those metals, closed at the outer end but open at the inner, is sealed through the glass wall of the X-ray tube, so as to project a short distance into

the tube, and for about 2 in outside This may, as shewn diagramatically in Fig 21, be sealed into a projecting side-piece of the tube, or into the anode stem, as in Fig 28 On the projecting part of the regulator being heated by the flame of a spirit-lamp or Bunsen burner, hydrogen gas passes into the interior of the tube and lowers the vacuum as desired The metal employed must possess the same co-efficient of expansion with heat as glass, otherwise the sealing would be impossible, but fortunately such metals are procurable

Platinum is the metal commonly employed, but its action is somewhat slow. Palladium, on the other hand, is very sensitive, and the process is difficult to regulate where it is

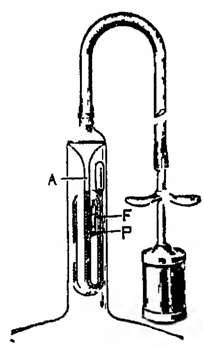


Fig 22—Diagram of Bauer Air Regulator

employed A compound of the two metals has been tried, and is said to give very satisfactory results with careful working

These metal regulator tubes are very easily damaged, and each should have screwed over it a protecting cap which should be removed only when it is desired to excite the regulator, or a wire cage as shewn in Fig 28

(*d*) **Bauer's valve** is an arrangement whereby a small quantity of air may be passed into an X-ray tube, so as to reduce the degree of vacuum as required In a side-piece open to the tube is a convoluted glass tube containing mercury, and connected at one end to a small air-pump, as shewn in Fig 22

A side-piece branching from this tube (at P) contains a porous plug (F), and opens at its distal end into the cavity of the X-ray tube Its proximal end is sealed off from the outer air by the column of mercury contained in the convoluted tube (as shewn under A) Compression of the air-pump forces the

mercury along the glass tube towards the reservoir at its end, thus unsealing the side-piece (at P), and air enters there, passes through the porous plug (F), and reaches the interior of the X-ray tube

Upon release of pressure by the air-pump, the mercury returns and again seals off the side-tube The air-pump may be operated at a distance while the tube is in action, and the term of service of the arrangement is in no way limited by capacity

This is an ingenious arrangement, but it is difficult to regulate the amount of air admitted and the consequent degree of softening

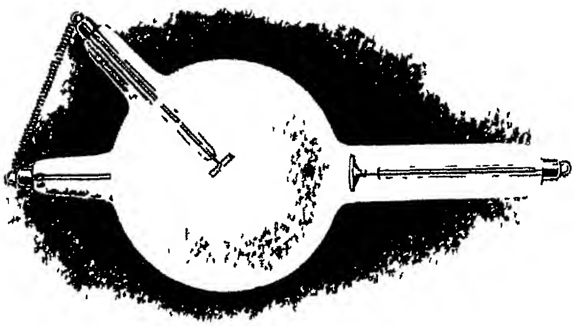


FIG 23—X-RAY TUBE WITH PLATINUM ANTIKATHODE

Over-Heating of Antikathode.

Not more than one-thousandth part of the energy supplied to an X-ray tube is emitted in the form of X rays, the remainder appears as heat, and that principally in the antikathode as result of the bombardment of that target by the kathode rays As already mentioned, with tubes of sharp focus this heating may be so intense at the focal spot as to volatilise the metal

For this reason, with the more powerful outfits now in use, tubes are employed with antikathodes made of tungsten in place of the platinum of earlier types The melting point of tungsten is about 3,200° C., whilst that of platinum is 1800° C. For moderate currents platinum is still preferred by some workers as being more constant and steady in working. Fig 23 shews a very simple tube with platinum antikathode, and the delicacy of its construction is at once apparent on comparison with Fig 24, which represents a modern tube designed for heavy work

As may be seen in the latter figure (as also in Fig 19), the tungsten target is in the form of a disc or button embedded in a mass of copper, special care being taken in the process of manufacture to secure excellent contact between the tungsten and copper

By this means the heat generated in the target is rapidly conducted into the copper mass, from which it is radiated along the metal stem connecting the antikathode to the metal cap at the outer end of the stem

In the "Leviathan" tube here illustrated the antikathode stem is hollow, and the whole inner surface is open to the air, thus facilitating the dispersal of heat

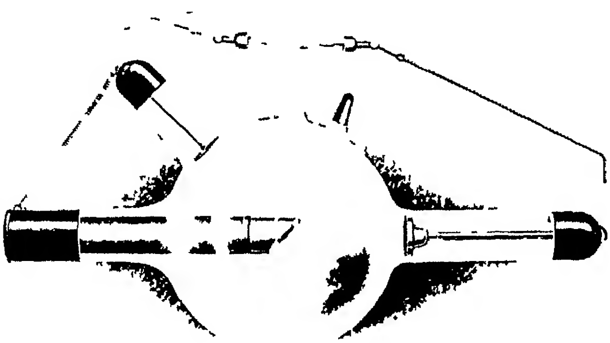


FIG 24.—X-RAY TUBE (THE "LEVIATHAN") WITH HEAVY METAL ANTIKATHODE

Special cooling devices are used in tubes intended for long-continued use, as in therapeutic work, and especially in recent developments of deep therapy

Of such devices the most useful are (*a*) water-cooled, (*b*) radiator, and (*c*) boiling-water, types

(*a*) **Water-cooled** tubes have the antikathode forming one end of a water-chamber, the water in which absorbs the heat from the antikathode, composed of platinum or tungsten, and from the metal vessel—usually of platinum—which forms its stem It is essential that the parts of such a tube should be designed so as to keep the water in close contact with the back of the target For the same purpose two forms of this type are made, for use according to the position in which the tube has to be placed during operation

The tube represented in Fig 25 is of the form usually

employed in practice for therapeutic work It is for such work that water-cooled tubes are specially serviceable—that is, for

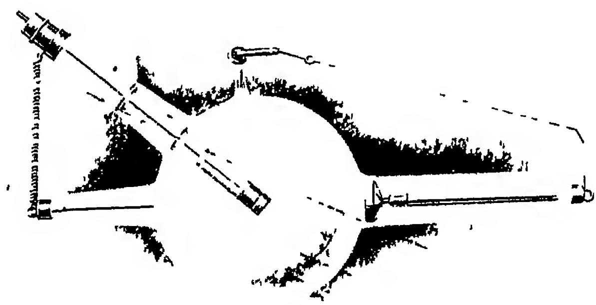


Fig 25 —X-RAY TUBE, WATER-COOLED

prolonged exposures with moderate current For very heavy discharges, as in rapid radiography, those tubes in their original form are not so suitable, because, with the very sudden rise in

Fig 26 —X-RAY TUBE, WATER-COOLED.
(For use in any position)

temperature, steam is at once formed behind the target-disc and separates the water from it The cooling effect is thus altogether prevented, and the disc—purposely thin—would probably under such circumstances become fused

For the same reason those tubes must never be run without water

Later designs of water-cooled tubes are made with reinforced targets—a platinum or tungsten target being embedded in a copper mass, which conveys the heat to the water-jacket, but for moderate currents this is not essential

The form in Fig 25 is only suitable for use over the couch or vertically, so for use in any position a second form, as shewn in Fig 26, is made Where much therapeutic work is being done with moderate currents, water-cooled tubes are very suitable, and soon compensate in economy of tubes for their extra initial cost

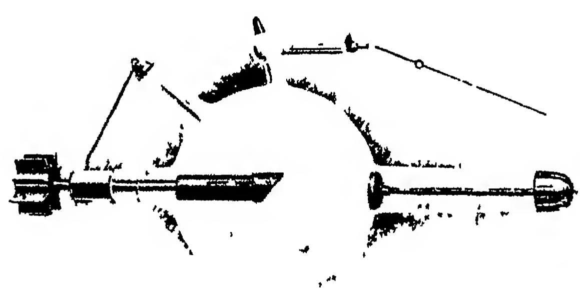


Fig 27—X-RAY TUBE WITH RADIATOR

(*b*) **Radiator** tubes, as their name implies, secure cooling of the antikathode by heat conduction along the metal antikathode stem to an external radiator The tube illustrated in Fig 24 is cooled partly by radiation, as noted in the context, but that is specially designed for dissipation of heat rapidly generated for but a short period More continuous dissipation of heat is attained by the addition of a special radiator, as seen in Fig 27, consisting of a series of blackened metal fins, as on a motor cycle engine cylinder A large surface is thus presented to the cooling effect of the atmosphere, which effect may be assisted by the employment of a fan to carry away the warm air and maintain a continuous supply of cooler air to the radiator surface

This method is employed in the smaller types of Coolidge tube, as illustrated on page 53

(*c*) **Boiling-water** tubes are a recent development, designed for use in deep therapy Produced first on the continent, highly efficient tubes of this type are now made in this country,

of which Fig 28 shews a successful design In the continental design the kathode, as well as the antikathode, is water-cooled, but in the design here illustrated a more convenient arrangement of cooling the kathode by a radiator is adopted

This tube is specially designed for use with very high potentials, up to 200,000 volts, and, to obviate external sparking, the length between terminals is proportionately greater than in gas tubes for ordinary use The over-all length is about 30 in, of which 16 in is accounted for by the kathode stem

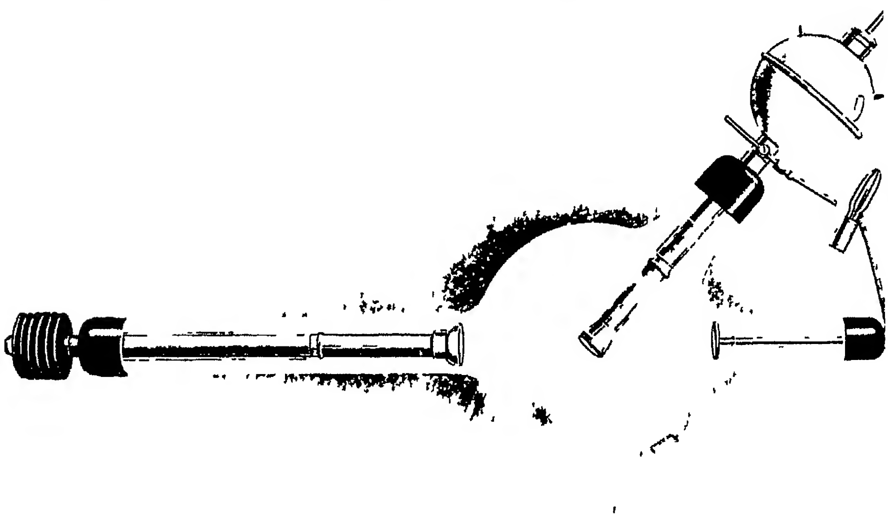


Fig 28.—Boiling-water Gas-filled X-ray Tube, with Osmo Regulation and Bunsen Burner for Automatic Control

The tube is quoted by the makers as intended to work with about 2 5 milliamperes at an equivalent spark-gap of about 16 in

The hollow antikathode stem opens into a massive water bulb, which is provided with a gauge to indicate the water level This indication is necessary, since the tube works normally with the water at boiling point, and loss by evaporation must be made up. Any heat generated after the water has reached 100° C. is dissipated in the formation of steam, and the target is thus prevented from becoming hotter than that critical temperature. The condition of the tube is originally very hard, and in action it becomes progressively harder, so that a vacuum regulator is essential to permit current to pass when first switched on, and also at periodic intervals.

The regulator is of the osmosis type described on page 38,

and may be noted in Fig. 28, enclosed in a wire cage and situated on a side-tube communicating with the anode stem.

The action of this regulator is made partly automatic by the arrangement of a small Bunsen burner, the gas from which is ignited by a spark which passes when the tube hardens beyond a certain degree. The arrangement may be made completely automatic by an ingenious device, whereby the gas supply is switched on whenever the current passing falls below a certain value due to the hardening of the tube.

When, by action of the regulator, the tube softens and the current rises again to the critical value the gas is switched off.

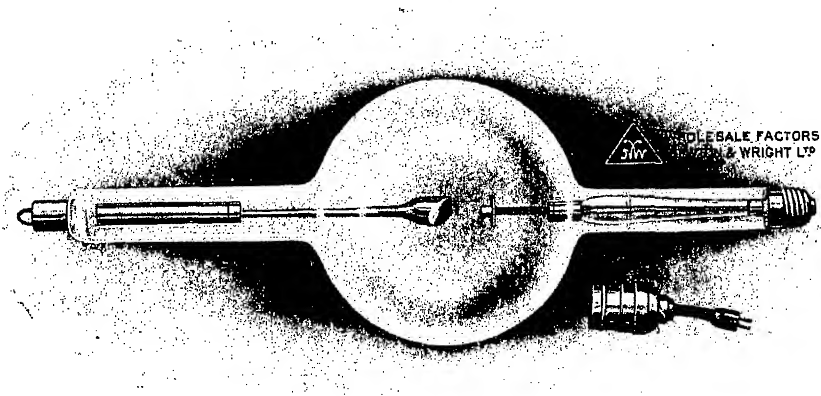


Fig. 29.—INCANDESCENT-KATHODE (COOLIDGE) X-RAY TUBE.

Incandescent-Kathode Tubes.

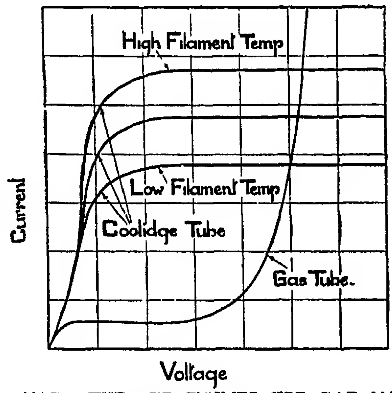
As mentioned in the introductory chapter, incandescent-kathode tubes of two kinds have been brought into use: the Coolidge tube in America, and the Lilienfeld tube in Germany, those having been produced almost contemporaneously.

It may be recalled that in gas tubes electric discharge across the tube depends upon the residuum of gas in the tube, whereas in incandescent-kathode tubes discharge depends upon the emission of electrons from the incandescent kathode. In the latter the gas in the tube is so completely exhausted that the kathode is the only source of electrons, and those are emitted in increasing quantity as the temperature of the filament is raised, so that it may be broadly stated, subject to a limitation noted later, that *the quantity of X-radiation depends upon the filament current.* As explained in Chapter I, the quality of

X rays depends upon the voltage applied to the tube, and as this can be varied independent of the filament current, the quality of X-radiation can be varied at will independent of the quantity, and it may be stated that *the penetration of X-radiation depends upon the applied potential*

The applied potential is varied by suitable modification of the primary current supplied to, or utilised in, the high-tension transformer, for which modification convenient arrangement is made, as explained later in Chapter IV.

Thus, the two factors of quantity and quality of X-radiation



CHARACTERISTIC CURVES FOR GAS AND COOLIDGE TUBES

Fig 30

are under separate and convenient control, whilst the range of either is amply sufficient to meet all present-day requirements

To understand the operation of incandescent-kathode tubes it is essential to study the principal characteristics of electron emission from hot filaments Fig 30 shews current-voltage curves for an incandescent filament and for a gas tube, and from that will be noted the marked contrast between the two characteristic curves

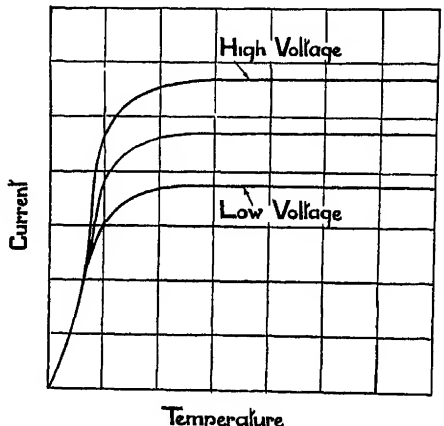
In the gas tube the current rises indefinitely with the voltage, in the incandescent-kathode tube the current for any given temperature of the filament rises only for a time, then it reaches a maximum "saturation" value and there remains constant, however the voltage may further increase

It is thus seen that at a given temperature the number of electrons emitted from the filament is limited.

Fig 31 shews another limitation. It might be inferred from the curves of Fig 30 that for a given voltage the current may be increased indefinitely by increasing the temperature of the filament, but the curves in Fig 31 shew that at a certain temperature (dependent upon the voltage) the maximum electron emission is reached

From these curves, plotted from experimental results, will be understood the limitations of the gas tube and the corresponding advantages of the incandescent-kathode tube

In the former neither the quantity or quality of X-radiation emitted can be controlled independently of the other, whilst



RESTRICTING EFFECT OF 'SPACE-CHARGE' ON CURRENT THROUGH A COOLIDGE TUBE

Fig 31

the condition of the tube during operation is liable to changes which unavoidably affect both properties.

In the latter, so long as the saturation voltage is exceeded, the two factors may be controlled independently, although, as is often not realised, a change in current may slightly affect the electrical conditions external to the tube and so alter the applied potential Thus, in raising the temperature of the filament and thereby increasing the discharge current, a drop in the applied potential will, as a rule, be caused, and the radiation emitted will be correspondingly softened

Compensation is easily made for this, however, by the regulation provided, as described in Chapter IV (on page 118).

A table or chart may be constructed to shew the relative

variations necessary, but by careful observation of the voltmeter and milliammeter the settings for any desired combination are easily found and noted before the actual exposure is made.

The Coolidge X-Ray Tube is the only incandescent-kathode tube used to any extent in this country The earliest type, and still the most commonly used—the "Universal" type—is shewn in Fig 29, and some details diagramatically in Fig 32

The vacuum of the tube is extremely high—said to be about one thousand times that of an ordinary X-ray tube.

Through such a vacuum it would be practically impossible to send a discharge under ordinary conditions. The usual disc-shaped kathode is replaced by a small flat spiral of tungsten wire (1 in Fig 32), through which a subsidiary electric current may be passed from an accumulator battery of 8 to 12 volts,

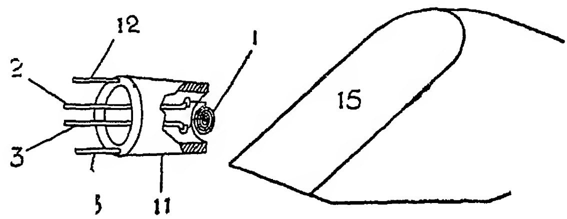


Fig 32—COOLIDGE X-RAY TUBE—ENLARGED VIEW OF KATHODE AND FRONT END OF TARGET

from a special filament-heating transformer, or from a tapping from the high-tension transformer employed for the passage of the main current (see page 54) The wire becomes heated by the current passed, thus causing the emission of electrons which serve to carry the main current across the tube, to an extent which increases rapidly with the temperature It is the impinging of those electrons at high speed upon the antikathode of the tube which causes the emission of X rays The tungsten spiral is surrounded by a tube of molybdenum (11), with which it is electrically connected, and the combination takes on the functions of the kathode The antikathode (15) is of wrought tungsten, is specially heavy, and is situated axially opposite to the kathode, about 2 cm distant In Fig 33 is shewn diagramatically the filament-heating arrangement with accumulators (B), the current passing through a rheostat (R), by which the amount passed through the spiral kathode may be regulated and correspondingly the temperature of the latter By thus adjust-

ing the temperature of the kathode the intensity of X-radiation produced may be precisely and readily controlled

An ammeter (A) is included in the filament-heating circuit, currents of 3 to 5 5 amperes being employed, but since a slight variation in the reading of this corresponds to a large increase in the resultant tube current, it is by many workers considered preferable to watch the latter directly, as indicated in the milliammeter shewn at (M)

An arrangement of apparatus for use of accumulators is shewn in Fig 39, as also a similar arrangement of a transformer in Fig 40, whilst a diagram of the connections of the latter is shewn in Fig 34, which demonstrates clearly the independence of the two controls

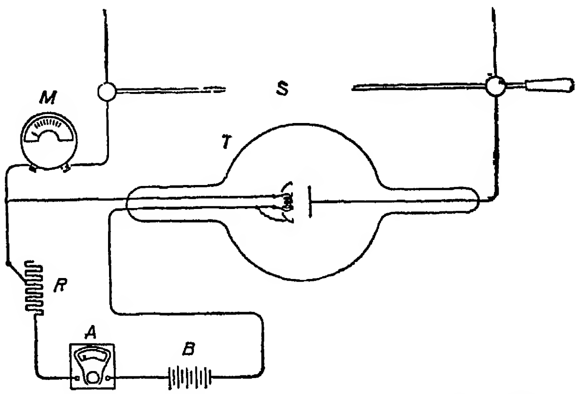


Fig 33—Coolidge X-ray Tube—Diagram of Filament-Heating Circuit.

The "Universal" Coolidge tube will successfully rectify its own current, provided that the energy used is not such as to heat the focal spot or any part of the anticathode to a temperature approximating to that of the kathode filament

It is not possible to ensure this condition in practice, so that only a uni-directional current should be applied to the tube, that is, the current must be "rectified," as described for the gas tube.

The radiator type (Fig. 35), described later, is more successful in eliminating inverse current, and for that reason is preferred for certain limited purposes.

As in the gas tube (page 40), overheating of the target must be avoided, and the *sharpness of focus* permissible is limited by this consideration Hence, for use under different conditions "Universal" tubes are made of (*a*) fine, (*b*) medium, and (*c*) broad focus, and recommended respectively for. (*a*) fluor-

oscopy and for radiographic work where sharp definition is desired and heavy currents are not required, (*b*) for general fluoroscopic, radiographic and light therapeutic work, and (*c*) for deep therapy and radiographic work where heavy currents are required

The energy input permissible varies correspondingly and should be kept always within certain limits for each class of tube This energy depends jointly upon the applied voltage and the current, and it is to the product of those two factors that a limiting value must be set When that limit is reached

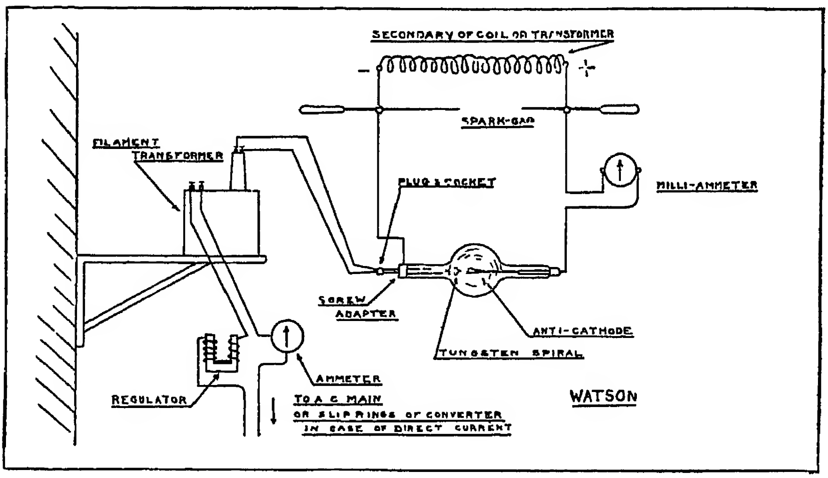


FIG 34.—CONNECTIONS OF COOLIDGE TUBE WITH FILAMENT-HEATING TRANSFORMER AND CONTROL

either factor can only be safely increased if a corresponding decrease be made in the other.

With an applied potential of about 100,000 volts (100 kilo-volts), equivalent roughly to a 6-in spark-gap between points, or 3 75 cm between 10 cm spheres, the current through a "Universal" tube should not exceed,

for a *fine focus*	. .	25 milliamperes,
for a *medium focus*	.	50 ,,
and for a *broad focus*	.	80 ,,

otherwise serious damage may be done to the tube

In operation the kathode filament should always be heated before the high-tension is applied to the tube Care must also be taken to see that the latter is not left applied longer than is necessary, since the quiet action of the tube fails to direct attention to its continued operation

In contrast to a gas tube, in which fluorescence of the glass may serve as a guide to the correct action of the tube, there is a marked *absence of fluorescence* in an incandescent-kathode tube, except perhaps for a small amount in the anode stem This absence of fluorescence is thought to be due to the accumulation of a negative charge on the glass sufficient to cause the repulsion of electrons approaching, or at least to cause such a reduction of their speed as to prevent fluorescence

Incidentally, no X rays will be produced at the glass surface, which constitutes an advantage since such secondary radiation is detrimental to radiographic results

Fig 35 shews a specimen of the **radiator type** of Coolidge X-ray tube This differs considerably in constructional details

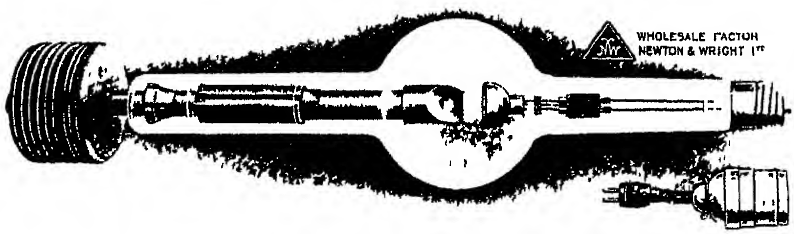


Fig 35—Coolidge X-ray Tube—Radiator Type

from the "Universal" type, but is similar in the main features of its operation

Its name is derived from the cooling device attached to the antikathode, which latter consists of a tungsten button embedded in a mass of copper, as in recent gas tubes From the copper mass the heat generated in operation is conducted along a connecting stem of copper to an external radiator of the same metal As the greater part of the heat generated in the tube is thus rapidly conducted and dissipated, it is possible to make the bulb much smaller in diameter than in other tubes dependent for cooling upon radiation from their glass walls

The kathode is similar to that of the "Universal" type, the focusing device surrounding the filament being cup-shaped as compared with the cylindrical form in the latter. A special feature which makes this type of tube of particular value under appropriate conditions is its great efficiency in automatic elimination of inverse current. Even when the focal spot

becomes as hot as the filament of the kathode, correct action is not interfered with, and the tube refuses to pass inverse current This is said to be due to the presence of gas in the target, but the action is not thoroughly explained In operation, however, the body of the anode should never be allowed to become hotter than is indicated by a dull red, and no tube should ever be pressed beyond the limit of safety indicated by the makers, this limit in each case being mainly dictated by the area of the

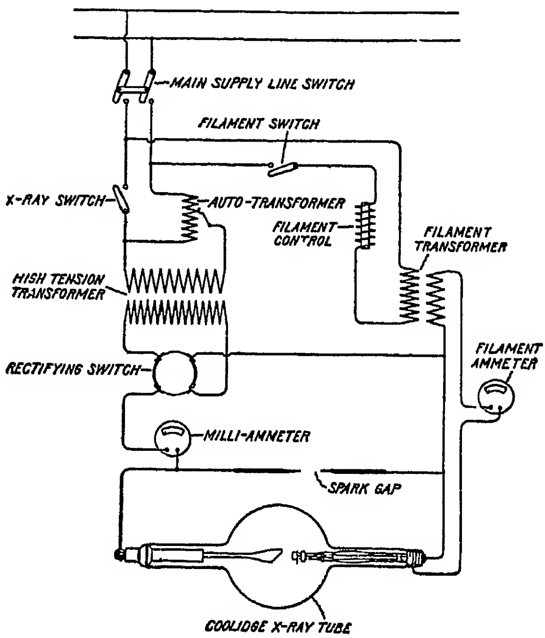


Fig. 36 —Connections of Radiator Type Tube on Unrectified Current

focal spot This tube being mainly designed for radiographic work, a somewhat fine focus is desirable, and upon the two classes of tube usually supplied a limit is set respectively of 30 milliamperes and 10 milliamperes, with a voltage not exceeding that corresponding to a 5-in spark-gap between points (about 90 kilovolts)

This amount of current should be safely carried by the tube for any required exposure in radiography, or it should carry 5 milliamperes as long as may be required for screening.

Fig 36 shows diagramatically the connections of a radiator tube, including a special filament-heating transformer This is the favoured method of heating the kathode filament in this

type of tube, and where A C current is available, it is decidedly preferable to the older accumulator control

This diagram shows connections on unrectified current, and the self-rectification of the radiator type makes it especially useful with such a current, but it may be used equally well on unidirectional or rectified current

A special *lead glass shield* of ingenious design is made for this radiator type of tube, and within the limitations of the use of that type is valuable and safe This is shewn in Fig. 37, whilst in Fig 38 is shewn, similarly enclosed, a modified form of the radiator type specially designed for use in dentistry

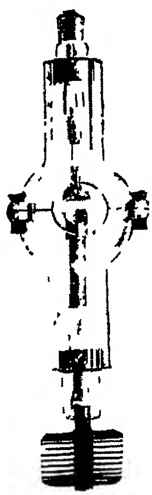


Fig 37 —Radiator Type Tube in Lead Glass Shield

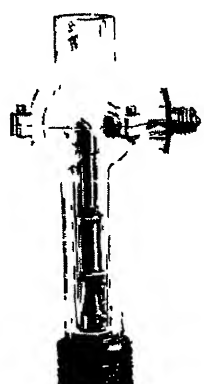


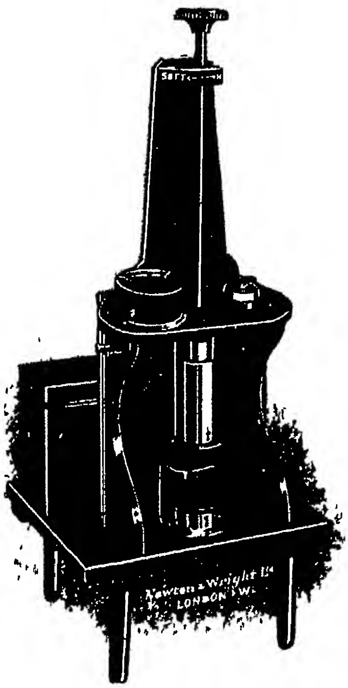
Fig 38.—Radiator Dental Type Tube in Lead Glass Shield

For use with a special portable outfit, a tube of 2½ in diameter is made of lead glass, except for a transparent window opposite the target The use of this is necessarily very limited, but for its special purpose it is a valuable design

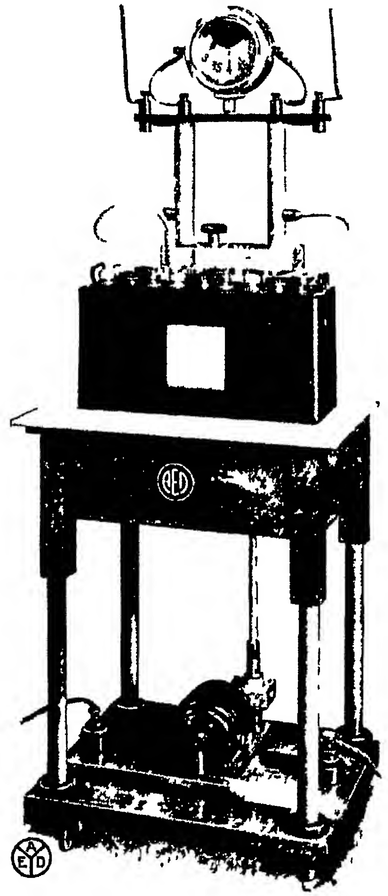
Filament-heating requires some auxiliary device in addition to the ordinary high-tension generator As mentioned earlier, this may take one of three forms (*a*) a battery of accumulators, (*b*) a special filament-heating transformer, or (*c*) a special tapping from the high-tension transformer employed for the passage of the main current

(*a*) *Accumulators* were commonly used in the early days of the Coolidge tube, as they were universally applicable and their use already familiar to most X-ray workers

The battery should consist of 5 or 6 (10 or 12 volt) 40 ampere-hour cells, suitably mounted and connected with a switch, an ammeter, and coarse and fine regulating resistances. A suitable set is shewn in Fig 39, and, as shewn there, such an arrangement must be thoroughly insulated from earth and from



39.—ACCUMULATORS AND CONTROL FOR ATING FILAMENT OF COOLIDGE TUBE.



39A.—BATTERY SET WITH ARRANGEMENT FOR DISTANT CONTROL.

the operator, as (from Fig. 33) it will be seen that the battery acquires the same potential as the kathode terminal of the tube.

This arrangement is not always satisfactory, and, except where direct current is alone available, it is being largely replaced by the transformer.

(*b*) *A static transformer*, specially designed, is more com-

monly used now for supplying the necessary current for heating the kathode filament. Such transformers are described in Chapter IV, and, for this purpose, are usually oil-immersed (*C* in Fig. 40), being arranged to step-down the main supply to the required voltage, and suitable controls (B) being arranged to regulate the amperage passing to the filament, as in the

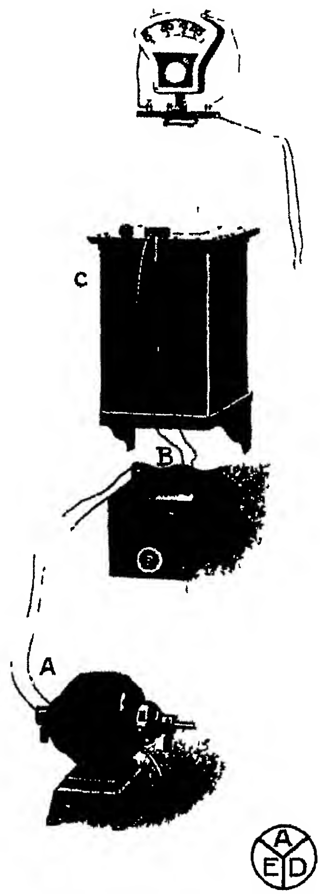


Fig. 40.—Filament-Heating Transformer and Control

accumulator set. Unlike that set, however, this regulator is not in direct connection with the high-tension current of the tube, but is inserted in the primary of the transformer, thus obviating the necessity of insulating all parts of the control and considerably reducing the chances of accident. The control is very convenient if attached to the main switch-table of the X-ray outfit, and may usually be so fitted, even to an existing table. Certainly in a new installation this should be arranged.

Where alternating current is available, such a transformer is undoubtedly preferable to the accumulator set, and should replace one even when installed, whilst for a new installation on direct current a small rotary converter (A in Fig. 40) should be added, and a transformer employed on the alternating current thus produced

(c) *A tapping from a high-tension transformer* of the interrupterless type should be employed where current to the tube is supplied from a machine of this type, as described in

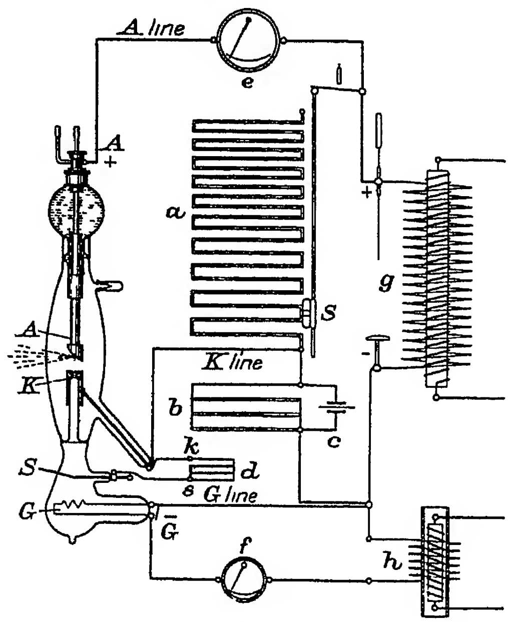


Fig 41 —Lilienfeld Tube.
(Reprinted from *The Electrician* of 29th April, 1921, from a paper by Dr. Kaye)

Chapter IV, pages 118, *et seq* This method in operation is similar to the separate step-down transformer described above, and its arrangement becomes a question of electrical design rather beyond the present purpose to discuss It will be understood more readily after perusal of Chapter IV.

The Lilienfeld Tube is shewn diagramatically, together with the electrical connections concerned in its operation, in Fig 41. This tube might be said to act somewhat as a combination of an incandescent-kathode tube and a gas tube, claiming the advantages of both. A special incandescent kathode (G) in an annexe to the main tube is separately excited

by a moderate potential from (*h*), and the electrons emitted pass through the proper kathode (K), which is hollow, and which is not heated. These electrons are subjected to a very high potential between the kathode (K) and the antikathode or anode (A), and thus attain the necessary speed before striking the latter. The electrical circuits are so arranged that the intensity and hardness of the rays can be independently controlled, so that essentially this tube operates very like the Coolidge tube already described.

Inverse Currents and Valve Tubes.

As stated earlier in this chapter, most high-tension generators

Fig. 42.—OSCILLOSCOPE TUBE.

of electricity produce both direct and inverse potential, and the necessity for eliminating the inverse phase has been emphasised. Many generators, during recent years, have been fitted with mechanical devices for the suppression of the inverse phase, and these will be described later along with the machines concerned. The inverse phase may otherwise be suppressed by the inclusion in the X-ray tube circuit of instruments known as *rectifiers* or *valves*.

Most modern interrupters are fitted with *mechanical rectifiers*, which will be found described on page 97, but in the absence of that arrangement, or for currents above 12 to 15 milliamperes, separate valves will be necessary. These may with advantage be described here along with an instrument known as an *oscilloscope*, used for detection of inverse current, since all are forms

of vacuum discharge tubes, in that respect resembling the X-ray tubes described in the preceding pages

An **Oscilloscope Tube,** as shewn in Fig 42 and mentioned above, is a form of discharge tube, and consists of a long narrow tube with an aluminium wire electrode from each end nearly meeting about the centre Some designs have a mica disc with a central hole between the two electrodes, but this is not essential The gas pressure in such a tube is not so low as that in an X-ray tube, if the pressure is too low the tube ceases to function On discharge of a purely unidirectional current through the tube a purple luminous gas layer appears around and along one of the wires—the kathode, whilst the other electrode is unaffected unless for some luminosity at its extreme point

The length of the glow on the kathode is approximately proportional to the strength of the current passing, and if inverse current be present it is indicated by more or less luminosity along the anode—which for the inverse current acts as kathode The length of this additional luminosity is a rough measure of the amount of inverse current passing Conversely, such a tube may serve to indicate the polarity of the circuit, since the luminosity if not confined to, will be at least more extensive along, the electrode connected to the negative terminal of the generator

Fig 43 shews the appearance of oscilloscope tubes under various conditions

The **Valve or Valve-tube** included in an X-ray circuit for the purpose of suppressing inverse current is, like the oscilloscope, a discharge tube with a gas pressure not so low as in the X-ray tube

Fig 44 shews a simple type of valve, made either single, double or triple, and will serve to illustrate the principle of action of such valves The pear-shaped tube has one end drawn out as a prolongation of the central space Into the main space projects a terminal of thick aluminium wire in the form of a corkscrew, and in the farthest part of the prolongation is the second terminal, formed by a slender rod, or disc, of aluminum. So long as the larger corkscrew-shaped terminal acts as a kathode the tube conducts easily, but to currents in the opposite direction it offers a high resistance. This valve action depends upon the fact that a discharge requires considerable free space around the kathode, whereas the anode of

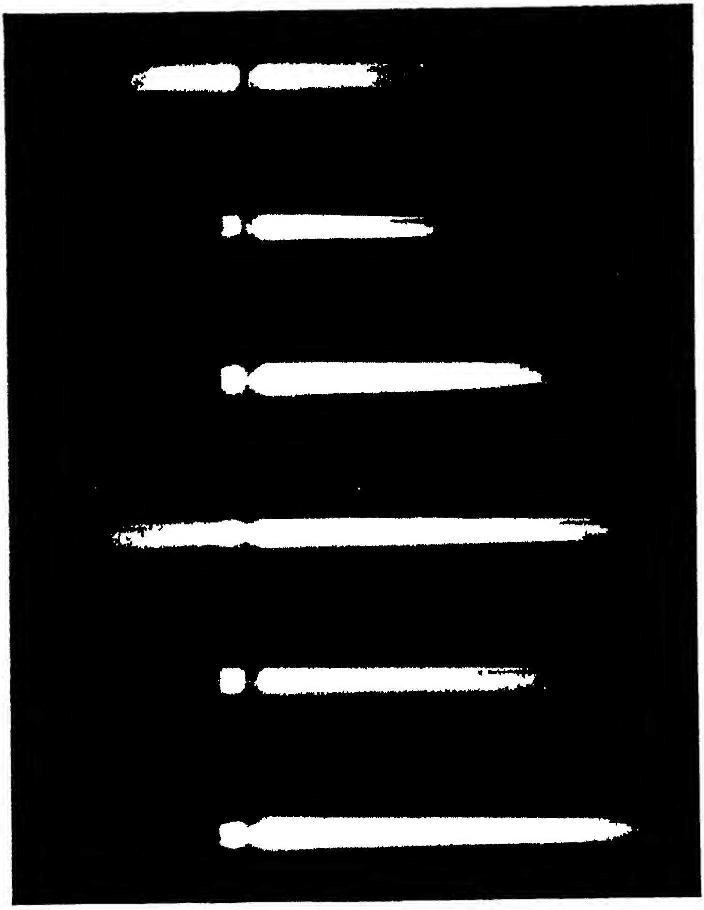


Fig 43 —OSCILLOSCOPE TUBE APPEARANCES

No. I was obtained with a wrongly constructed induction coil The intensity of the inverse current is nearly as great as the intensity of the direct current. The number of milliamperes could not be measured on account of the large percentage of inverse current

No II was obtained with a good coil The M.A meter registered 5 M A No valve of any kind was used in the secondary circuit

No III —The M A meter registered 15 M A No valve of any kind was used Inverse current just begins to appear

No. IV —With still heavier current No valve of any kind in the secondary The M A meter gives no correct information on account of the inverse current.

No V was taken under exactly the same conditions as No IV, but a spark-gap was inserted in the secondary circuit, and reduced the inverse current very much. The M A meter indicated 18 M A

No VI was taken with a coil designed for exposures with one single flash A valve tube was inserted in the secondary circuit, 30 M.A. were indicated by the M.A. meter.

The illustrations show the luminous bands a little less than half actual size.

this tube is well withdrawn into the slender stem, and can only with great difficulty act as a kathode as required for passage of inverse current. If this tube be placed in proper relation to

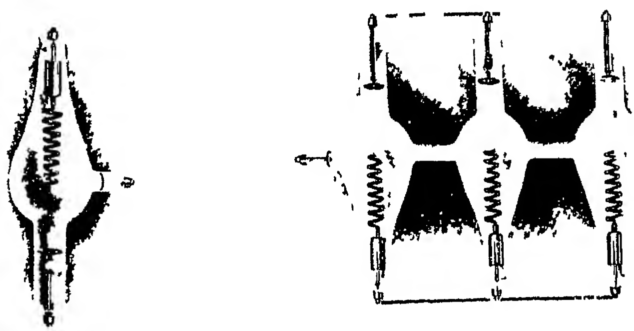


Fig. 44.—Valve Tubes—Single and Triple

the X-ray tube, it will readily be seen how it will oppose the passage of inverse current, whilst allowing easy passage to the direct currents desired for use The anode of the X-ray tube, should of course be towards the positive pole of the *generator*,

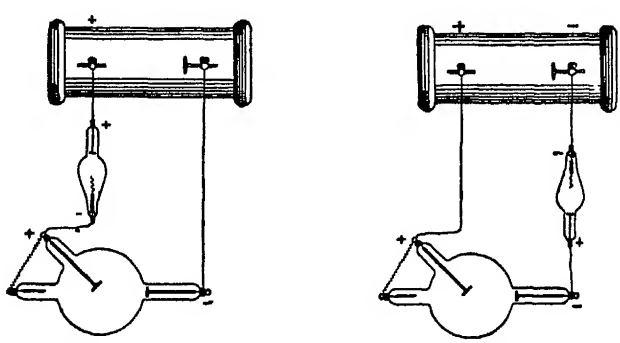


Fig 45.—Method of Connecting Valve Tubes

(1) When at the positive pole, and
(2) When at the negative pole, of the Coil.

and the valve-tube should be interposed on one side or the other in such a position that the spiral acts as kathode for the direct current, as shewn in two alternative positions in Fig 45

In practice the valve-tube should be interposed between the generator and the sparking pillars, otherwise the alternative spark will measure the resistance of the valve-tube in addition

to that of the X-ray tube, and thereby convey a false idea of the condition of the latter. Care should be taken, however, not to allow discharge sparking to take place freely whilst the valve-tube is in this position, because the tube has to carry the heavy current of the sparks and may thereby receive damage.

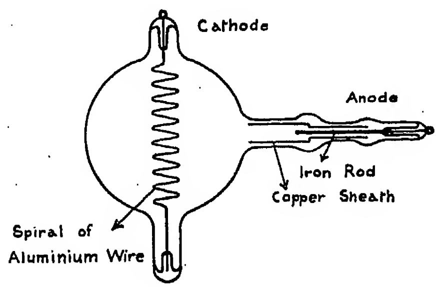


Fig. 46.—DIAGRAM OF A LODGE VALVE-TUBE.
(Reproduced, with permission, from Kaye's "X-Rays," Longmans Green & Co.)

Fig. 46 shews a modified design, due to Sir Oliver Lodge, in which the anode is of iron wire surrounded by a copper sheath, and is placed in a long side-piece branching from the main tube. This arrangement serves to prevent sputtering on the glass

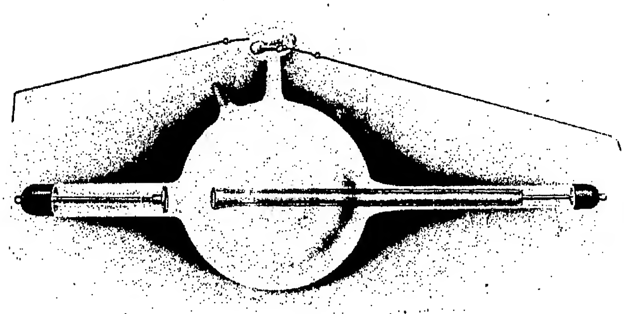


Fig 47.—VALVE-TUBE WITH REGULATOR.

walls and increases the resistance of the tube to inverse current. The Lodge tube is very efficient in action, and hardens very slowly, if at all, with use, owing to a special method of treatment during exhaustion. A long working life is thus ensured.

Another modified form of valve is shewn in Fig. 47. It is similar in action to the valve shown in Fig. 44 and described above, and is a very efficient instrument.

With this, as with other valve-tubes of similar type, a vacuum regulator should always be attached, as considerable hardening occurs with use The tube cannot rectify efficiently under such conditions and needless resistance is introduced into the circuit

Valve-tubes in use should not be allowed to become hard, but should be worked with a pressure which gives some luminosity in the body of the tube and a slight apple-green tint round the kathode base This luminosity may be somewhat inconvenient in a darkened room, so that some means of screening the tube may be necessary A "hard" valve-tube may emit an appreciable quantity of X rays, which fact should be borne in mind when protection is under consideration

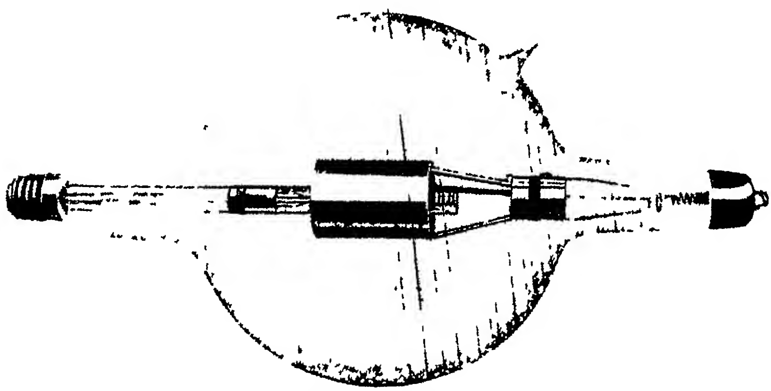


Fig 48—Incandescent-Kathode Valve Tube

For heavy work—as in rapid radiography—multiple valve-tubes are advisable Such a multiple tube is shewn in Fig 44, the single tube of that type being intended for use in installations where current of more than 5 M A. is not employed

The double and triple valves will rectify proportionately heavier currents

In place of such "batteries" an *incandescent-kathode valve-tube*, similar in action to the X-ray tube of the same type, may be employed for very heavy currents from large induction coils The rectifying action of these valves depends upon the fact that current can only pass with the heated electrode acting as kathode, and current in the other direction is consequently suppressed

An auxiliary circuit for heating the kathode filament is required, consisting of items similar to those described in

connection with the incandescent-kathode X-ray tube on p. 54. For ordinary work this is a relatively costly device, and its operation demands considerable attention, but for currents heavier than can be dealt with by the mechanical rectifier or simpler valve tubes, it is undoubtedly most efficient, being quoted as reliable up to 100 milliamperes.

For most purposes, valve-tubes are a most efficient and economical arrangement for preserving the X-ray tube from inverse currents, but for lighter work an **adjustable spark-gap** may be used. This, as shewn in Fig. 49, consists of a point and plane forming opposite electrodes of a spark chamber. Its action depends upon the fact that current passes more readily

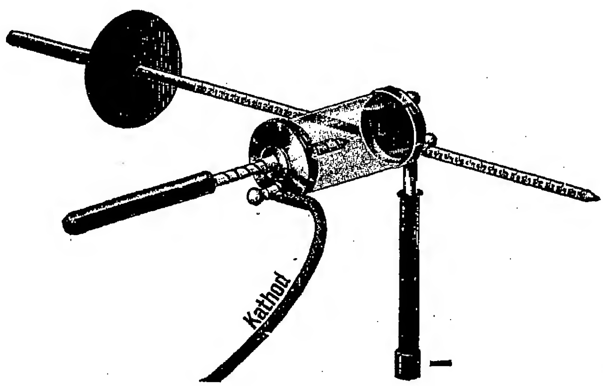


Fig. 49.—ADJUSTABLE SPARK-GAP.

in sparks across the gap when the point is positively charged than when it is negatively charged.

Fig. 49 indicates its proper connection. Such an arrangement is used commonly, and efficiently, with static machines and for light or moderate currents. With heavy currents it becomes noisy, and with currents such as are used for rapid exposures an arc tends to form across the gap and the current is not rectified. It is, however, for suitable work convenient and economical, as there is practically no deterioration by prolonged use, and the arrangement allows easy regulation to suit the resistance of different X-ray tubes and consequent variation in current. For a current of about one milliampere a spark-gap of one centimetre or a little more is suitable.

By screwing the point home till it touches the plate the spark-gap may be abolished; by screwing back the point the

resistance can be increased gradually, till the light in the tube indicates that the inverse current has ceased.

Where tubes of different hardness are used in succession, this ready means of regulation is of great value, and its effect on the appearance of a tube is often very striking

With heavy currents and an enclosed gap not sealed from the atmosphere acids and moisture due to the chemical action of the discharge collect in the enclosure and nitric acid fumes may escape into the air of the room Such an arrangement is therefore apt to call for frequent attention and prove somewhat unsatisfactory in regular use.

CHAPTER III

SOURCES OF SUPPLY

Main, D.C. and A C.—Accumulators—Generating Sets—Static Machine

THE source of supply of electricity for X-ray work may be one of a number of varying description

The work to be done will dictate the choice where that is an open one, but more often the choice will be dictated by the factors of convenience and economy relative to the installation under consideration

The method commonly followed for all-round work in this country is to employ a *continuous current* of 100 or 200 volts, and to convert that to the high potential necessary to operate an X-ray tube by passing it through an induction coil

Where the supply available is not continuous, it is frequently most satisfactory to convert it into that form if the use of an induction coil is contemplated This may mean initial expense, but, where any serious amount of work is to be done, that will soon be compensated for in convenience and economy of working

Attention has been increasingly directed of late towards more direct use of *alternating current*, and improvement in apparatus for that purpose is leading to modification of the decided preference for continuous current in X-ray work

This change has been brought about largely through the development of the closed magnetic circuit, or interrupterless, transformer for high-tension work, and the successful combination of this machine with the incandescent-kathode tube

The *static machine* has, at various times, been recommended, and possibly, with alterations in construction, that machine might find increasing favour in this country, but climatic and other conditions render its use somewhat uncertain in its present forms

The various sources of supply ordinarily available are —

I **The Main.** This is the most satisfactory source, and may be (1) **direct or continuous**, (2) **alternating**.

II **Accumulators**

III. **Gas, oil, or petrol, generators.**

IV. **Static machine.**

I The Main.

1 **Direct or continuous current from the main**, where available, should be used direct for any permanent installation

If at a voltage not exceeding 240 volts, the current may be sent through a switch-board to the high-tension generator, whether in the form of a coil and interrupter or of an interrupterless closed-magnetic-circuit transformer

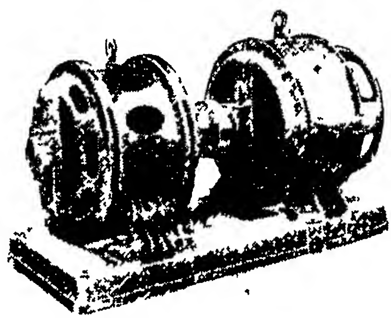


Fig 50—MOTOR-TRANSFORMER

A **motor-transformer** should be used where the character of the supply requires alteration Such a machine, as shewn in Fig 50, consists of a motor of horse-power dependent upon the required power of the outfit, constructed to run at the voltage of the main supply, and connected direct to a dynamo wound to generate current at the desired voltage.

For use with an induction coil and interrupter suitably designed a voltage of 200 gives the best results, provided that, by design of coil and by inclusion of mechanical or other rectifier, the suppression of inverse current is secured

The dynamo should be capable of supplying 12 to 20 amperes of current for ordinary use

A motor-transformer is extremely easy of manipulation, and, beyond ordinary care of lubrication and attention to brushes of the generator, requires no attention, expert or otherwise.

The starting-switch is usually made of a form such that the driving current may be gradually increased to the maximum, since the full current, suddenly switched on to the motor winding, would do serious damage to it. In ordering this machine the voltage of the supply must be noted, as well as the nature of the current desired to be generated for use.

A word of warning is here called for, which applies to any dynamo in which the only load is that of an induction coil In the first place, relatively high potential surges will be received from the coil back to the dynamo, resulting in dangerous potentials between the windings and the frame of that machine, unless the leads have sufficient capacity to obviate the rise of potential

In addition to this, owing to the fact that the current taken by the coil is an interrupted current, high potentials will be induced in the armature of the dynamo unless a dynamo of specially low armature inductance be selected

These points will be better appreciated by the non-electrical reader after the principles of high-tension generators have been studied in Chapter IV, but it is important that they should be borne in mind by X-ray workers, as they are frequently overlooked by electrical engineers called in to advise in the selection and installation of a suitable generator.

A satisfactory method of meeting the danger is to provide a machine of slightly greater power than that required for the X-ray installation, and to shunt it with a non-inductive resistance which will take a load of 10 to 20 per cent of that taken by the induction coil This resistance will take the "extra current," and thereby prevent a dangerous rise of potential.

2 **Alternating current.** Until recent years it was the accepted practice to convert current from an alternating supply into continuous current of suitable voltage for X-ray work by means of a **motor-transformer**, the motor being wound to drive off the alternating circuit, and being coupled direct to a dynamo designed to supply continuous current as desired.

The above note and illustration (Fig. 50), describing motor-transformers for converting the voltage of continuous current from the main, apply equally to those designed for converting alternating current In the latter case it is necessary, in ordering, to state the voltage of supply, its *frequency*, and its phase—single, triphase, etc

The development, and the more extended use, of the

interrupterless transformer, which operates on alternating current, and the production of a number of satisfactory designs of induction coil outfits to operate directly on that type of current, have provided suitable alternative methods and removed the necessity for conversion of alternating into continuous current unless for special reasons The induction coil outfits here mentioned are satisfactory for light work, but their capacity is definitely limited, and for heavier work they are therefore unsuitable

II Accumulators.

Accumulators or **Secondary cells** may form valuable sources of direct supply for use with a suitable induction coil and interrupter—

(1) Where portability is of prime importance ,

(2) Where the apparatus available is designed for low voltage only ,

(3) Where there is an existent source of supply, but not convenient for direct connection by wiring to the X-ray installation ,

(4) In occasional cases where supply is available, but not of a nature for direct use.

Where an X-ray outfit is chosen mainly with a view to **portability** the advantage of accumulators will depend largely upon convenient opportunity of recharging them, since they can by no means be made to produce electricity unless charged from an electrical supply

The trolley set shewn in Fig 51 was provided in the late war for use in wards where electrical supply wires could not be tapped

With some such arrangement, and in the **absence of a convenient direct supply** for a permanent installation, accumulators may be used after being charged elsewhere , but if much work is to be done it is better to instal some form of generating apparatus to provide a direct supply. This will be understood when the process of recharging accumulators is considered, for if a primary source be inconvenient, then the chances are that the accumulators will not be recharged so frequently or regularly as they ought to be in order to preserve their efficiency Under such circumstances, also, transport of the accumulators renders this a troublesome and costly method for regular working The use of accumulators may,

however, be combined with the installation of a primary source of supply, where that may be more conveniently or economically brought into action at periodic times.

Where a **supply** of any nature is **available intermittently,** accumulators are eminently serviceable to render the energy available as it may be required

For **conversion** of an unsuitable regular supply accumulators may prove of service for utilisation of alternating current which may, by special arrangement, be utilised for charging the cells

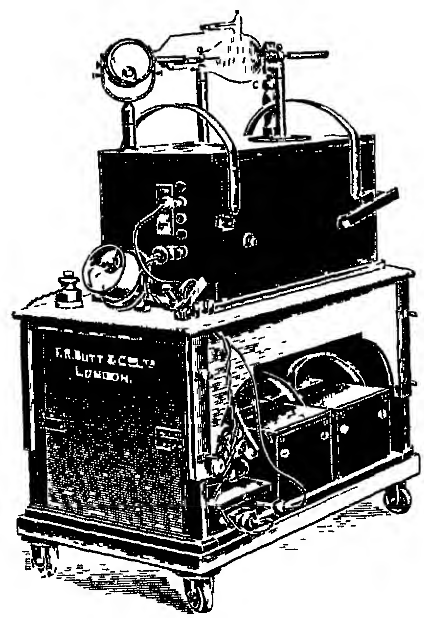


FIG 51 —PORTABLE (WARD) OUTFIT WITH ACCUMULATORS.

In most cases some of the other means suggested will prove commendable, but each case must be considered in relation to its own special conditions

Where the use of accumulators is indicated it may be necessary for the X-ray worker to superintend their recharging, and to see personally that they are maintained in a state of efficiency This personal responsibility may be obviated if the cells be sent to an electrician, or to a generating station, where expert attention may be expected, but such may prove a most inconvenient and costly mode of working Further, it may be under circumstances which render it impossible to obtain expert assistance that accumulators will be found most useful

The operator being thus directly responsible, it was decided, in earlier editions of this work, to enter more fully into the questions of charging and working accumulators than into most of the other details dealt with. For men in army or navy service it was intended that this should be especially useful, but, except under very exceptional circumstances, the use of accumulators for modern X-ray work becomes increasingly limited, and it has been decided in revision to curtail somewhat the notes on accumulators and omit the directions for charging, so as to devote the space at disposal to more modern developments Handbooks on the care of accumulators are obtainable, where these are dealt with from the engineer's

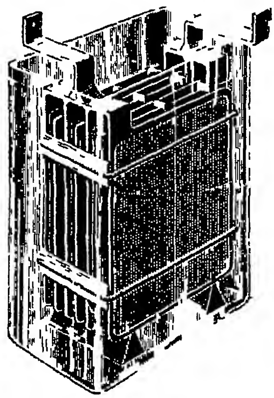


Fig 52—Secondary Cell or Accumulator

point of view, and for more pertinent detail readers may refer to the earlier editions of this work. Where accumulators are in use, however, unless the radiographer happens to have experience in their care, he will be wise to enlist the assistance, if possible, of someone who has such experience

Accumulators are often spoken of as "storage cells" of electricity. This they are in effect, for, after receiving an appropriate "charge" of electricity, they may be kept for some time, and thereafter a "discharge" of electricity obtained from them An electrical current, passed through an accumulator cell, produces chemical changes in the constitutents of the cell which thereafter stores energy in a potential form, represented by the tendency of the constituents to return to their former condition

An external circuit being completed between the terminals

of the cell so charged, its constituents more or less gradually resume their former condition, and the potential energy thus liberated appears in the form of electrical effects in the circuit

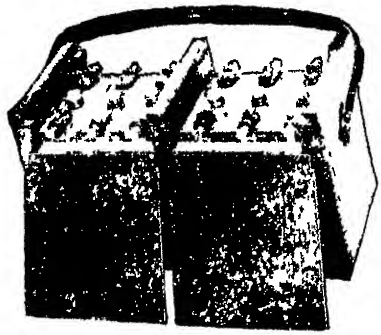


Fig 53 —Portable Accumulator Set

The chemical changes referred to are somewhat complicated, and a full explanation is not here attempted

Each cell (as shewn in Fig 52) contains several lead plates

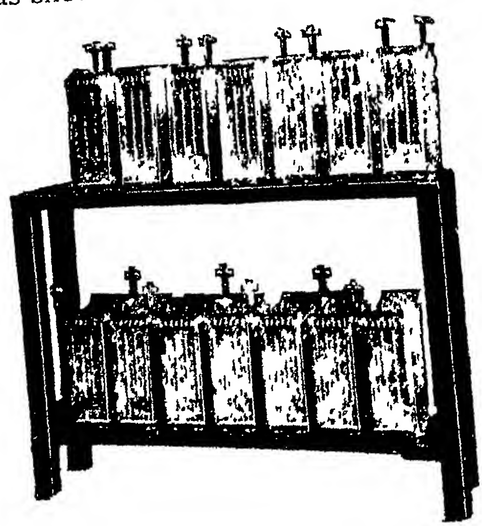


Fig. 54.—Storage Battery Set on Wood Stand

connected alternately to the positive and negative terminals of the cell, and all are immersed in, and well covered by, dilute sulphuric acid.

During charging a current of electricity is sent through the cell from a suitable source of supply By electrolytic action

there are produced from the acid quantities of free oxygen and hydrogen The former appears on the plates connected with the positive pole, converting them gradually into peroxide of lead, whilst the hydrogen appears on the negative plates, reducing them to a porous, spongy mass of metallic lead. Those actions on the lead plates having proceeded as far as possible, the gases escape in bubbles from the liquid, thereby indicating the completion of the charging process. In discharging, those processes of oxidation and reduction are reversed, the plates return to their previous condition, and the acid regains its original strength

Thus the process may be repeated any number of times in the same cells, if due precautions be observed

Accumulators for X-ray work are generally arranged with several cells in a box, as in Fig 53, this arrangement being convenient for connections and for portability Where the

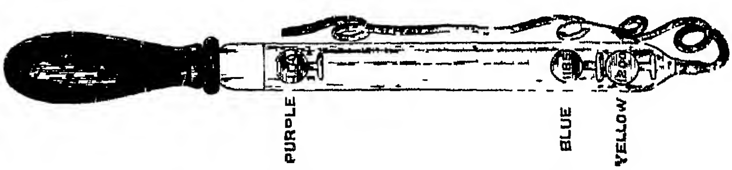


Fig 55 —Acidometer for Accumulators

latter may be of no consideration the cells are arranged on an open stand, as in Fig 54, freely open to inspection The cells are connected in series—that is, the negative pole of one is connected to the positive pole of the cell adjoining it, leaving at one end of the box a free positive terminal, and at the other a free negative terminal. The E M.F of each cell being fully 2 volts, a box of four cells will give, when fully charged, at least 8 volts Three or four such boxes are as a rule employed for portable outfits, thus obtaining an E M F of 24 or 32 volts for use

The number of plates varies, but frequently in each cell (as in Fig 52) there are seven plates, three positive and four negative The positive plates are of a dark chocolate colour, while the negative are of a slaty-grey The dilute sulphuric acid in which they are immersed should be of a specific gravity of 1190, attained by adding 1 part of pure H_2SO_4 to 5 parts of water The diluted acid should, when cold, be tested by a hydrometer supplied for the purpose, of which the principle and method of use will be recalled by reference to Fig 55. The

pecific gravity should be adjusted, if necessary, by addition of ıore H_2SO_4 or water according as the indicated density is ıelow or above the desired standard.

The capacity of an accumulator depends mainly and directly ıpon the quantity of peroxide of lead in its plates, and is xpressed in ampere hours. Thus, "60-ampere hours" signifies hat an accumulator can discharge 1 ampere for sixty hours, amperes for thirty hours, etc As, however, the capacity ıecomes smaller as the discharge rates become higher, a ıuotation of the capacity should always be accompanied by a ıuotation of the discharge rate

Frequent recharging tends to preserve the efficiency of ccumulators, and they never work better than when used and

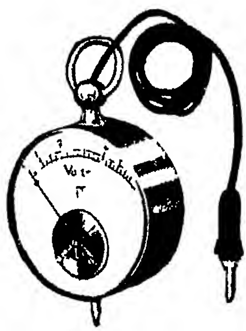


Fig 56—POCKET VOLTMETER

echarged daily Even when not in use, they should be ıccasionally recharged—about once in every three weeks—to eep them in good order If one goes off for a holiday, they hould be fully charged before being left.

If left at rest in a charged condition for any length of time, ccumulators tend to deteriorate, but they do so much more apidly if left standing discharged

They should never be fully discharged in working, the safe ımit being indicated by a fall in the voltage of the derived urrent Each cell, as mentioned, gives a little over 2 volts vhen freshly charged, and the bulk of its charge (about 75 per ent) is given off at that voltage. When the **E.M.F.** derived rom a battery of accumulators **falls** below 1 8 volts from each ell connected in series, it is imperative that it be **recharged at ınce.** The voltage should be tested frequently by a voltmeter, convenient pocket instrument for the purpose is shewn in Fig. 56

If, after recharging, the battery does **not register its normal voltage**, each cell should be tested separately with the voltmeter or a 2-volt lamp, so as to discover which cells are at fault Directly after charging each cell should register 2 4 volts

Short of serious damage, the diminution in capacity of a cell, and consequent rapid fall of voltage in use, is frequently due to a fall in the level of the acid, caused by leakage or evaporation (The possibility of leakage points to the necessity of having accumulators placed on leaden trays if they be kept indoors)

In testing for a fault, it is a dangerous plan to spark or flash each cell by connecting its opposite plates by a piece of wire, since such short-circuiting injures the plates

The chance of such short-circuiting by accidental means must be prevented Thus, in connecting up the induction coil, the ends of the connecting wires should be fastened to the coil before the other ends are fastened to the terminals of the accumulator, thereby avoiding the chance of live ends coming into contact Similarly, it is well to see that the accumulator boxes are not used as a shelf for depositing odd pieces of wire or metal, which may readily bridge the terminals and cause serious damage In extreme cases, by such short-circuiting, plates may be completely "buckled"

With careless working, it may soon be noted that an accumulator will **not absorb nor discharge the certified quantity** of electricity

This is usually due to "**sulphating**"—that is, the formation of lead sulphate in a crystalline form, which may be seen as white patches on the positive plates In a charged cell at rest there is always some leakage of current, and, as in usual discharge, lead sulphate is formed This, as first deposited, is soft, and easily altered by recharging, but if that be long postponed the deposit becomes crystalline, and is no longer altered by the current This deposit reduces the available area of lead, and the capacity of the cell is consequently decreased Plates much affected become useless and should be replaced by new ones

The obvious **remedy** is **frequent recharging.** Where insoluble patches have already formed, they should be scraped off with a piece of glass or other non-conductor

To prevent sulphating the addition of 1 ounce of caustic

da to 5 gallons of the electrolyte is sometimes tried, but reful working should obviate trouble from this source

Treated properly, a set of accumulators should do good rvice for many years, but the various points mentioned must constantly attended to

III Gas, Oil, or Petrol Generator.

A dynamo driven by a gas, oil, or petrol engine, forms a luable source of supply where such must be instituted in the sence of, or independent of, a general supply Thus, on ard a ship in which electric light is not installed, in hospitals

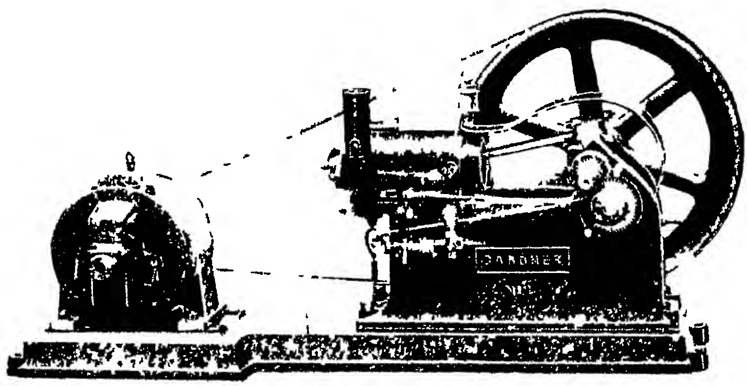


Fig 57—Oil Engine and Dynamo

isolated or country districts, or specially adapted for field rvice, this type of supply has much in its favour

The dynamo may be constructed to supply current suitable r the special purpose in view, and some amount of regulation ill be possible for variation of speed, though for each machine ere is a certain rate of speed at which the greatest efficiency obtained

The choice of a special form of driving power will depend ainly on the circumstances of the installation

Where there is a pre-existent supply of power, with sufficient argin, the dynamo should, if possible, be driven from that, ther by a direct, or chain or belt, drive

Where no power supply exists, and the installation is to be ationary, a small gas, oil, or petrol engine will usually be the

preferable power for driving Special circumstances may make a steam engine preferable Where a sufficient water power is available and convenient, an economical drive may be obtained from a water turbine This plan is highly commendable, wherever possible

Where portability is a main consideration—as for field service—various special adaptations may be employed The

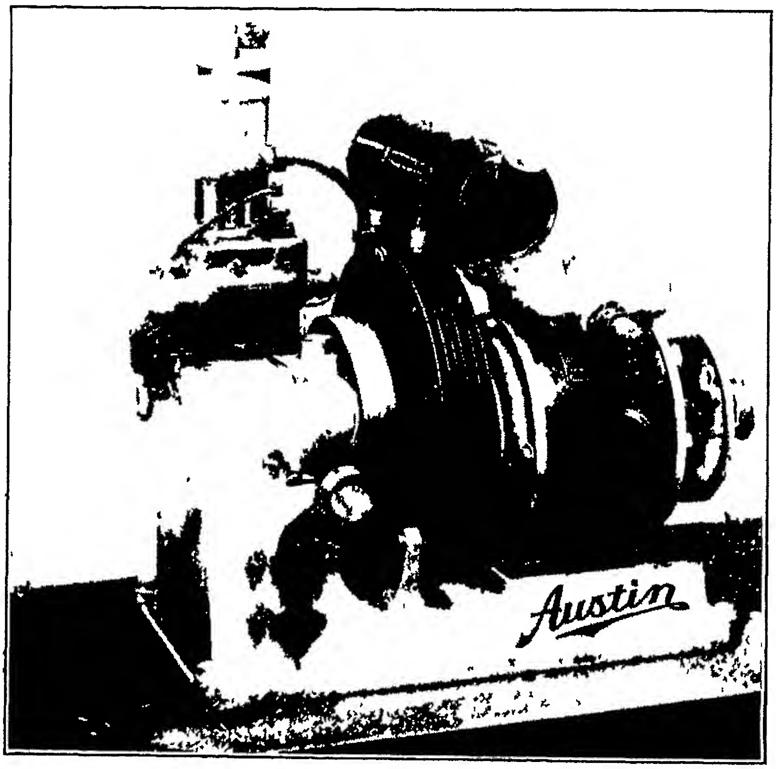


Fig 58 –PORTABLE GENERATING SET

dynamo itself should be of as light a pattern as may be compatible with efficiency, and the power unit a petrol engine of light design. Fig 58 shews a petrol engine and dynamo belonging to an X-ray outfit specially designed during the late war for portability.

Driving power may be derived from one of the traction engines or motors now so generally employed in transport.

Special automobiles are designed to transport a complete

X-ray outfit, the dynamo being coupled to the motor engine, the whole composing a self-contained and compact unit to accompany armies in the field.

An outfit of this kind was standardised for use by the Army Medical Service in the late war, and much excellent work was done by those "mobile units," but for portability the arrangement proved somewhat too massive.

Subdivision of the unit into loads for two lighter mobiles would probably be preferable.

In connection with generating sets for use with induction coils the precautions already referred to on page 67, regarding the dynamos of motor-generator sets used for the same purpose, should be observed.

IV. Static Machine.

Static or Influence Machines form a possible, and for some purposes an excellent, source of supply where portability is of no account. They have the great advantage of being self-contained; for one of these machines can supply current direct to the X-ray tube without addition or intervention of other apparatus, apart from the means of driving it. For the same reason, they are as a rule simple to use, though at times somewhat uncertain in action.

For screen-work they produce brilliant, steady illumination with a suitable tube, and are for this purpose excellent. For radiography, a tube so excited requires a long exposure, owing to the limited output, but very good radiograms may be produced.

Absence of inverse current and the improbability of over-heating prolong the life of the tubes considerably.

As mentioned at the beginning of this chapter, the static machine was, for a time, a favourite source in other countries, but in this country it finds little favour for practical installations because of the difficulty and uncertainty of its action, which uncertainty is partly due to climatic conditions.

A current of constant high potential is relatively more efficient in the production of X rays than the intermittent potential commonly employed. It was at one time thought that a static machine yields an output of constant potential, and that if improvements could be made in the static machine, so as to produce higher output and greater constancy in operation,

this machine might yet take a prominent place as a generator of high-tension current for X-ray purposes

Recent work, however, casts doubt upon the constancy of

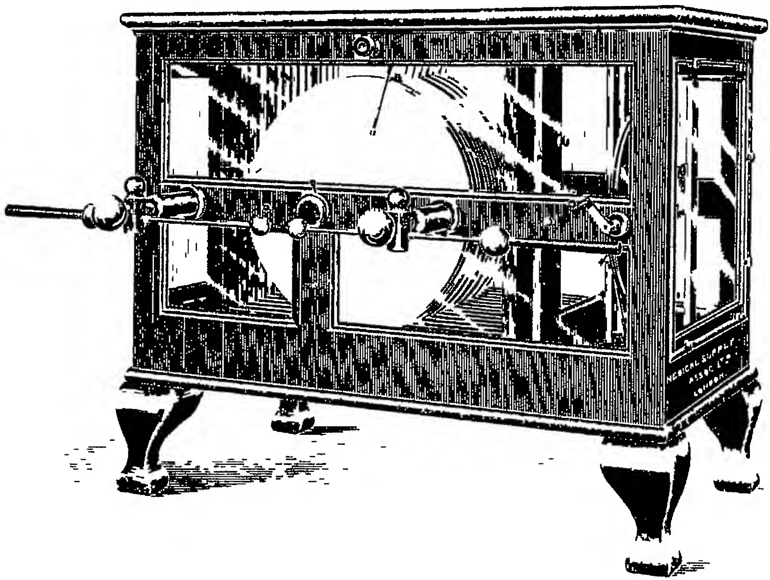


Fig 59—Static or Influence Machine

potential so generated Fig 59 represents a modern type of static machine, and will recall their appearance. For further details reference should be made to works on static electricity, where those machines are specially described and considered.

CHAPTER IV

HIGH-TENSION GENERATORS AND ACCESSORY APPARATUS

Electro-magnetic Induction—High-tension Current—Induction Coils — Interrupters — Interrupterless Transformers — Switchboards—X-ray Units—Fluorescent Screens—Vertical Screening Stands — Tube Stands — Tables — Diaphragms — Compressors—H.T. Fittings—Protective Devices

For excitation of an X-ray tube we have seen to be required a source of very high potential, approximately five hundred times that in ordinary use for electric light and other purposes

No source other than a static machine directly supplies current of such a high potential, therefore, except in the case of such machine, a transformer must be interposed between the ordinary source of electrical supply and the X-ray tube. Two types of transforming apparatus are in use Until 1908, **induction coils,** with separate interrupter attached, were the only practicable apparatus for the purpose, but in that year **a high-tension interrupterless transformer** was introduced for X-ray work

Such interrupterless transformers have since been largely used for rapid radiography, especially where alternating current is available That type of current is essential for these machines, and where direct or continuous current only is available, a motor-converter must be employed to change it to alternating

The induction coil has, however, been markedly improved in recent years, and for all-round work is still very largely used

Before describing these two forms of high-tension generators, with their accompanying accessory appliances, the physical principles upon which voltage transformation depends are explained in the following notes

Electro-Magnetic Induction.—It is well known that accompanying an electric current is a magnetic field, which is

such that if the current-bearing wire be wound into the form of a solenoid, it behaves as a bar magnet, with north and south poles, as indicated in Fig. 60.

The strength of this magnet is increased a thousand-fold or more if the solenoid is filled with iron, this arrangement constituting an electro-magnet.

To fix ideas and to correlate the facts of experiment, the magnetisation is represented by lines called "lines of induction" (when in air sometimes called "lines of force"), which are regarded as passing through the solenoid from south to north, and externally back from north to south, thus forming closed loops. Stronger magnetisation is represented by a larger number of lines, and, as the strength of the electro-

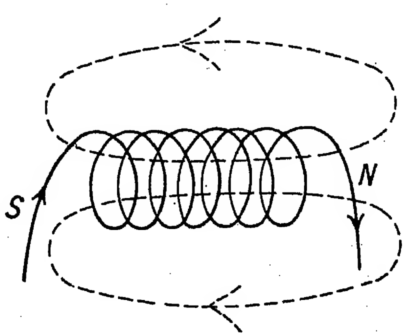


Fig. 60.—SOLENOID WITH "LINES OF INDUCTION."

magnet increases up to a certain limit with the increasing current, the number of lines will depend upon the strength of the current. Any variation in the strength of the current will consequently cause a corresponding variation in the number of lines passing through the solenoid.

It was discovered by Faraday that when the number of lines threading a coil is rapidly varied, there is induced in each turn of the coil an E.M.F. proportional to the rate of variation; hence the term, "lines of induction."

Consequently, if the current through the coil be suddenly stopped, the coil becomes the seat of an E.M.F. which, in a coil with an iron core and a large number of turns, may amount to thousands of volts.

The direction of the E.M.F. is such as to oppose the change which is being brought about, namely, the cessation of the original current.

Similarly, if the current be suddenly made, an E.M.F. is induced in the opposite direction, tending to oppose the passage of the current.

It is possible to stop the current suddenly by mechanically breaking the circuit, but obviously it is not possible to establish the current so rapidly on account of the opposing effect referred to above.

Induced E.M.F. in a Secondary Coil.—If a second coil be wound around the first, and its circuit be closed, the same inductive effect will operate in the "secondary" coil as operates in the primary, and a current will flow through it during the period in which the number of lines of force is changing. This arrangement is shewn diagramatically in Fig. 61. If the secondary coil consists of a very large number of turns, the

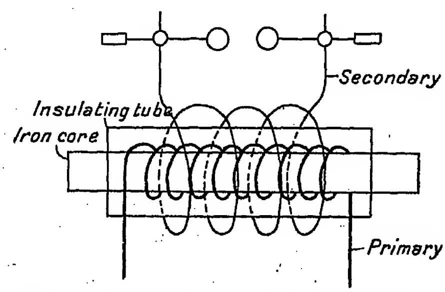


Fig. 61.—DIAGRAM OF INDUCTION COIL.

E.M.F. will be correspondingly high, since each turn contributes its quota of E.M.F. Hence, by using as the primary coil a small number of turns of thick wire carrying a heavy current and introducing a core of soft iron, a large E.M.F. may be induced in a secondary coil of many turns of fine wire by the sudden interruption of the primary current.

A high E.M.F. in the opposite direction is also induced when the circuit is made again, but not so high as at break, as it is impossible for the current to rise suddenly to its full value.

The heavy current through the primary may be obtained from a low voltage, such as that of an ordinary electric supply and, by application of this phenomenon of electro-magnetic induction, the transformation of that low voltage to a very high one is made possible.

By rapidly repeating the make and break of the current in the primary circuit an intermittent high E.M.F., alternating in direction at make and break, will be obtained.

To prevent currents from being induced in the iron core of the primary solenoid, which is, of course, a conductor of electricity, the core should be made of thin strips or wires not in intimate contact with each other, so that conduction in the direction of the induced E M F 's is not possible Such induced currents would lead to a waste of energy

Voltage Transformation with Alternating Current.—A similar result to the above is obtained if alternating current be sent through the primary coil, but since the rate at which the current changes is not so great as with sudden interruptions, the E M F induced in the secondary coil is not so high.

The high E M F with interrupted continuous current depends further upon the rapidity with which the core of the solenoid is demagnetised, and an open magnetic circuit is a

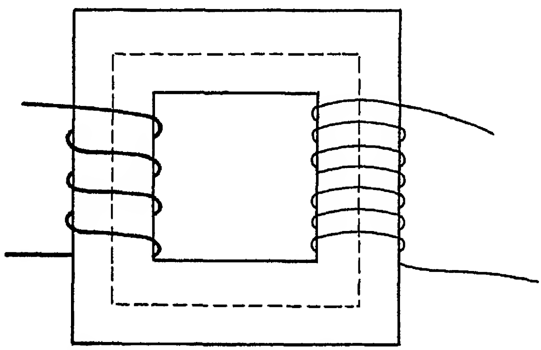


Fig. 62—Closed Automagnetic Circuit.

great advantage for this purpose With alternating current there appears to be no advantage in having an open magnetic circuit, since the rate of change of the number of lines of induction is fixed by the rate of change of the current When alternating current is used the magnetic circuit is therefore closed, as shewn in Fig 62

The lines of magnetic induction then form closed loops in the iron, as indicated by the interrupted line in the diagram. From this it will be seen that the secondary coil need not be wound outside the primary, as the total number of lines produced by the primary pass through the iron, and the same effect will be obtained by winding the secondary on another part of the magnetic circuit With this arrangement, since all the lines produced by the primary pass through the secondary, the voltage transformation is the ratio of the number of turns in the secondary to the number in the primary.

The energy efficiency of the closed magnetic circuit transformer approaches 100 per cent., whereas that of the open circuit induction coil is much less (although it will be seen later that this relation does not necessarily hold when efficiency in production of X rays is considered).

From energy considerations it will be obvious that if the voltage is raised the current must be correspondingly reduced; thus, the current in the primary, measured in amperes, will produce a current in the secondary measured in milliamperes.

In the foregoing outline of the principles of electro-magnetic induction is given the fundamental features of the induction coil and the interrupterless high-tension transformer employed

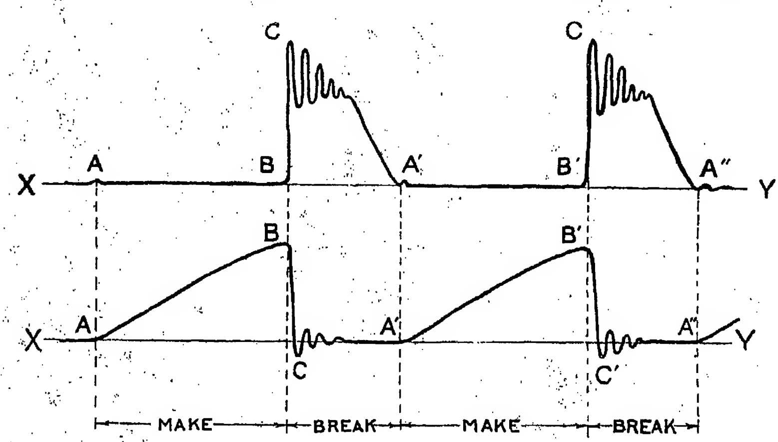


Fig. 63.—Curves of Primary and Secondary Current in an Induction Coil.

in X-ray work. The former is characterised by the use of interrupted continuous primary current (interrupted alternating current being sometimes used) and an open magnetic circuit; the latter by the use of uninterrupted alternating current and a closed magnetic circuit.

Types of High-tension Current.—The contrasting effects of those two arrangements are shewn in the graphs of current obtainable from the two types of instrument. In Fig. 63 are shewn curves of primary and secondary current in an induction coil discharging through a spark-gap.

No inverse current during the establishment of the primary is shewn. Under certain circumstances this is automatically eliminated, but under other conditions it requires to be cut out by means of a valve, as already indicated.

The wavy portions of these curves is due to the inclusion of a condenser in the primary circuit, the reason for which will be explained later, when the induction coil and its accessories are more fully described.

Fig. 64 shews the current curves obtained from an interrupterless transformer, with alternating current passing through the primary and the inverse phase of the secondary eliminated.

Those curves in Figs. 63 and 64 are copied from curves obtained by means of an *oscillograph*, which is an instrument for automatically recording potential or current variation; and in many such curves there are additional features of minor importance which are not reproduced above. The figures will

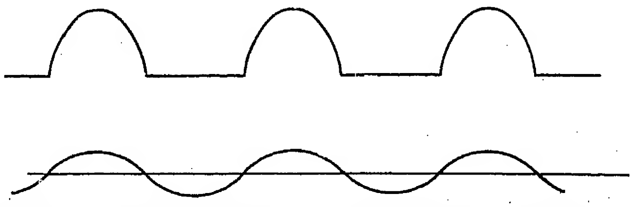


Fig. 64.—CURVES OF PRIMARY AND SECONDARY CURRENT IN AN INTERRUPTERLESS TRANSFORMER.

serve, however, to indicate the principal features, and it should be noted that—

(*a*) The curves of the coil are much more "peaky" than those of the interrupterless transformer, this indicating much more sudden changes; and that

(*b*) With both instruments, more particularly with the coil, the duration of current flow is but a fraction of the time available.

Owing to the much greater output of X rays at higher applied potentials, it is important to send as much current as possible through the X-ray tube at those higher potentials. The later part of the current from the coil, as shewn by the secondary curve, and both the early part and the late part from the interrupterless transformer, as similarly shewn, produce very little X-ray output and serve mainly to heat the X-ray tube. This lack of X-ray production has been directly shewn by superposing on the oscillograph records of current a photographic impression produced by the X rays simultaneously emitted from the X-ray tube.

Only opposite the higher portions of the oscillographic curve is there evidence of photographic effect; thus showing

that only at the higher potentials there represented is there sufficient intensity of X rays produced to affect the photographic plate. In this connection it may be recalled that the intensity of X-ray production is proportional to the square of the voltage. The heating of the X-ray tube produced by the lower voltages is not only useless but undesirable, and it is therefore advantageous to cut out as far as possible those portions of current. In this respect the induction coil has some advantage over the interrupterless transformer in its present design, but developments to secure the desired effect are being made in the design of both instruments.

A current of constant high potential would, for similar reasons, be more effective in X-ray production than either of the two types of transformer commonly in use at present. A promising arrangement of apparatus has recently been produced, in which high-frequency alternating current is modified by condensers and incandescent filament valves, so as to produce a constant high potential. With this or similar arrangement much more efficient generation of X rays may be anticipated.

Inverse Currents.—Frequently with a coil, and inevitably with an interrupterless transformer, an inverse current accompanies the direct in the secondary circuit and, as mentioned above, this inverse current must be eliminated. With both instruments attempts have been made by automatic reversal of direction to utilise the inverse phase so as to contribute to the X-ray output.

In the case of the coil, the inverse potential is seldom more than 50 per cent. of the direct, and the X-ray production from it is consequently slight. No useful purpose therefore is served by its inclusion, as milliamperage and tube heating are merely increased without a corresponding increase in X-ray intensity.

In the case of the interrupterless transformer inverse and direct potentials are of the same order, and a useful purpose is therefore served by the inclusion of both phases. By arrangement of a rotating commutator, suitably timed and running synchronously with the alternations, this may be accomplished, and such is the usual practice, as explained later.

The foregoing explanation of the principles involved leads now to consideration of the practical details of the induction coil and the interrupterless transformer respectively, together with their accessory apparatus.

Induction Coils.

Induction coils used in X-ray work differ in form and size, according to the designs of different makers and, more generally, according to the nature of their intended use.

Thus different designs will be found for *portable* and *stationary* sets

A coil designed for portability, of which an example is here shewn in Fig 65, is usually of "box" type, and has a relatively small secondary voltage.

The coil is here embedded in wax, enclosed in a strong case of teak, oak or mahogany, the inclusion of an interrupter in the case is optional and only suitable for low power coils

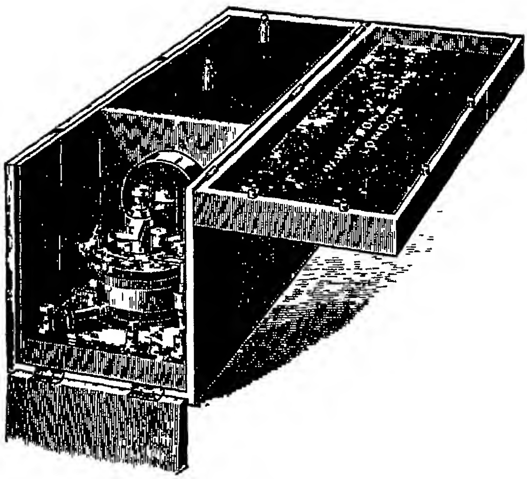


Fig 65—Portable Induction Coil.

There is no essential difference between such a box coil and the usual standard form shewn in Fig 66, and a few of the latter are also made in the box form.

More commonly, however, the standard type is cylindrical in shape, the coil being embedded in wax enclosed in a cover of sheet ebonite, except for the ends, which are of wood

The wax in which the coils are embedded is required for insulation purposes, it being essential to insulate highly the various coil sections or layers from each other. The primary coil is contained in a tube of ebonite, known as the primary tube, which serves to insulate the primary from the secondary coil (see Fig. 61) The primary tube projects at each end beyond the limits of the secondary, so as to prevent sparking between

the primary and secondary windings, and the requisite thickness of ebonite in this tube depends upon the construction of the secondary winding—whether "multisectional" or "bisectional." Each of those types of winding has advantages, the multisectional coil, for example, being more easy to repair but requiring a much stouter primary tube; but for particulars of this difference in construction and for other details some standard book, such as M. A. Codd's "Induction Coil Design," should be consulted.

The secondary winding of a coil comprises a very large number of turns of fine copper wire, amounting to miles in length. The ends are brought out through the wax to suitable well insulated terminals, which are constructed to facilitate

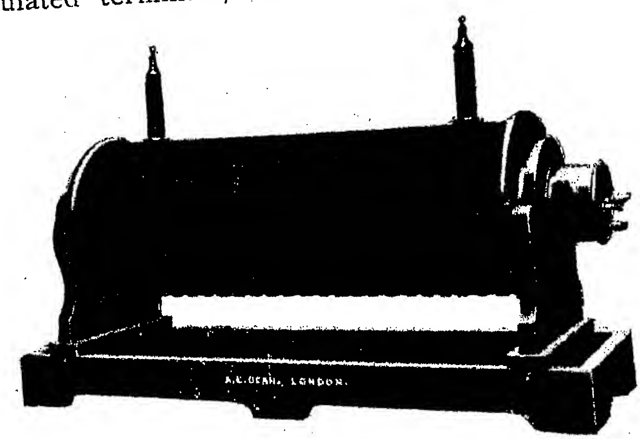


Fig. 66.—STANDARD INDUCTION COIL.

connection by leads, also well insulated, to the X-ray tube and other instruments required in the circuit.

The primary winding consists of a few turns of heavy copper wire, wound over a bundle of iron wires or stampings, which form the core, the turns being insulated by wrappings or ordinary insulating tape, and the ends are brought out through the end of the ebonite tube to terminals suitable for connection to the switchboard, interrupter, etc. Some primary windings are provided with several terminals, permitting the use of various lengths of winding as may be required, this being a very useful arrangement where the coil is required to operate on various supply voltages or with mercury and electrolytic breaks alternatively.

The voltage of the output of a coil depends upon the current used in the primary, upon the number of turns in the secondary,

and upon the efficiency of interruption of the primary current. With a relatively large number of turns in the secondary winding and a proportionately high voltage produced by the coil, the efficiency of insulation becomes increasingly important.

Coils are frequently listed as "10-inch," "12-inch," etc., up to "20-inch" coils, which classification represents approximately the maximum equivalent spark-length between points which the coil is capable of standing without breaking down.

This standard is, however, somewhat arbitrary and is not a true index of relative merit or efficiency in X-ray production.

For radiographic purposes a coil nominally 12 in. meets all requirements so far as voltage goes, and the real test from an X-ray standpoint is the relative output of current under standard conditions as regards secondary voltage and character of interrupter, condenser and primary winding. Thus a coil unit, or any other high-tension transformer, should be rated according to its capacity to pass milliamperes of current through an X-ray tube of stated hardness whilst operating from a standard supply.

For any particular installation the supply should naturally be that available at the site of the installation, and the tube hardness that requisite for the class of work to be undertaken. For radiography the latter factor is usually taken as equivalent to a spark-gap between points of 5 in.—about 90 kilovolts, peak value. (See page 14).

For deep therapy much higher voltages are being required than for radiography, and recent striking developments have been made in coils for the former purpose, but those are outside the scope proposed in the present work. For rating purposes, however, the same criterion should be applied, and this is particularly important where comparison is sought to be made between transformers of different type.

For operation of an induction coil certain intermediate, or accessory, pieces of apparatus are required, and the efficiency of the coil's action may depend to a large extent upon the proper design and arrangement of those accessories.

Fig. 67 shews diagramatically the primary and secondary electrical circuits of an induction coil and its accessories.

Interrupters and Condensers.—As we have already seen, the current supplied to an induction coil must be a regularly interrupted current, and to produce such interruption an auxiliary

piece of apparatus is usually employed, known as the *interrupter* or *break*

Across the terminals of the interrupter should be connected a *condenser* of suitable strength and capacity, whereby the efficiency of the interrupter is greatly increased

When the primary current is broken some sparking necessarily occurs, and there is a tendency to form an arc at the interrupter contacts, thereby delaying the break of the current, in quenching this arc a suitable condenser is of great assistance

Further, the oscillations of the condenser cause a more rapid demagnetisation of the iron core of the primary winding By

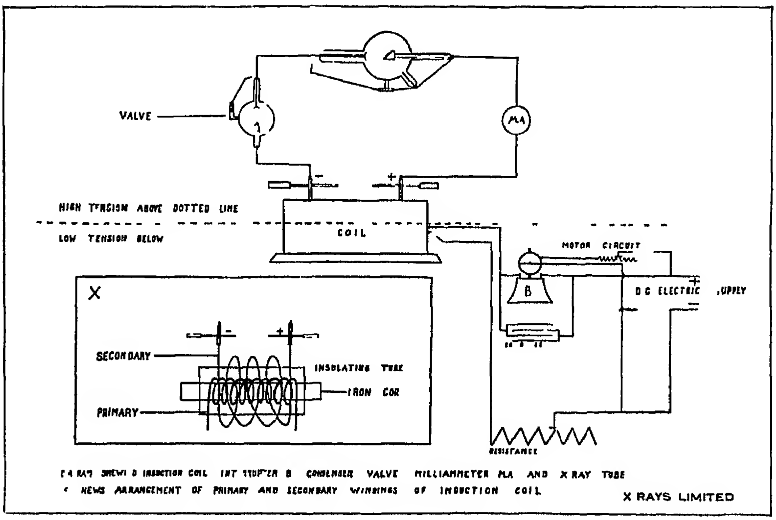


Fig 67.—Primary and Secondary Circuits of Induction Coil and Accessories

those two influences the use of a condenser greatly increases the spark-length and output of a coil

These three pieces of apparatus—coil, condenser and interrupter—should always be considered jointly, and designed mutually to suit one another Different breaks produce very different rates of interruption, and no single coil can be expected to work efficiently with widely varying rate of interruption Thus, a coil with a primary winding and core designed to suit a low rate of interruption will not be efficient with an interrupter giving a much higher rate of interruption, and, conversely, a coil wound to suit a high rate of interruption cannot respond efficiently to the longer periods of excitation

allowed by a more slowly acting break The length of each contact during which current is allowed to pass to the coil is also determined by the interrupter, and may be varied according to the result desired For this also the coil and interrupter should be mutually adapted

Many workers have made the mistake of applying to the same coil interrupters of varying construction and rate of interruption, and have been prone to judge the interrupter according to the result obtained, possibly ascribing failure to the construction of an interrupter rather than to the true reason of inco-ordination between it and the coil employed

Further, a coil may be badly handicapped or damaged by using with it a break different from that with which it was designed to work Thus, by substituting a break in which the current is allowed to pass for a longer period than with the break originally used, the coil may be seriously injured

The choice of coil and interrupter depends upon the demand likely to be made on them—that is, upon the nature of the work to be done

For **radioscopy** or screen examination a steady fluorescence is required, hence rapidity of interruption will be the criterion For **radiography** the same high rate is not essential, but will lessen the requisite length of exposure Since those two classes of work are usually combined, a fairly high rate of interruption, up to 3,000 per minute, may be considered essential

In **radiotherapy**, on the other hand, there is no especial call for rapid interruption, and a rate of 1,000 per minute will be sufficient for such work The duration of exposure will here frequently be much in excess of those employed in the other classes of work, so that, unless the apparatus be designed to stand such prolonged runs, it may be unable to withstand the strain

Where one or other class of work distinctly preponderates, the installation should be designed to suit that work, where neither preponderates, a compromise may be struck, unless the installation may be duplicated A radiographic outfit should not, however, ordinarily be used for treatment, nor should a treatment outfit be expected to produce good radiograms Some recent coils are made with arrangements for adjustment to suit varying conditions, and with an interrupter of wide margin of rate may be made to suit the work in hand, but never so efficiently as a coil designed specially for specified conditions

With a knowledge, then, of the nature of the work to be done, the radiologist may settle what rate of interruption will be most suitable, and he will have a coil built to suit, but first he will settle on the interrupter likely to fulfil the conditions

An important point in the action of an interrupter may be here noted—namely, the **break** of the current must be as **sharp and sudden** as it can possibly be made

Interrupters or breaks have been used of many different types, which may be classified as—

1 Vibrating, hammer, or platinum
2 Motor mercury, including—
   (*a*) Dipper type,
   (*b*) Turbine or jet type
3 Electrolytic

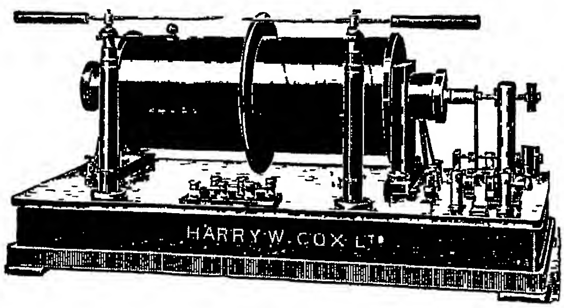


Fig. 68—Coil with Platinum Interrupter.

1 The familiar **vibrating or platinum interrupter** (Nieve's hammer), or one of its more recent modifications, is still used occasionally on a coil as interrupter, and, for a time, was admitted as serviceable where portability is of prime importance The rate of interruption is, however, greatly limited, about 1,000 per minute being a maximum, nor can voltages higher than about 20 volts be safely used, as their action with higher voltages is not reliable enough to safeguard the coil. The slow rate of interruption makes their use very unsatisfactory for screen work, since it produces an unsteady illumination, and the smaller currents permissible necessitate long exposures for radiographic work. Despite these disadvantages, satisfactory radiograms have been obtained with such an arrangement, as where circumstances required transport of apparatus to the bedside A very high rate of interruption should not be aimed at, since with that there is no gain in efficiency. Fig 68 will

recall the arrangement of this form of interrupter attached to the induction coil

The condenser is here enclosed in the wooden base, a fairly common practice

In this interrupter the magnetisation of the iron core of the coil is employed to produce the interruption of the current, the core when magnetised attracting towards it an iron armature (or hammer), of which the stem forms a link in the primary circuit That circuit is completed through a platinum point on the back of the armature, which is normally held by a spring in contact with a similar point on a regulating screw When the

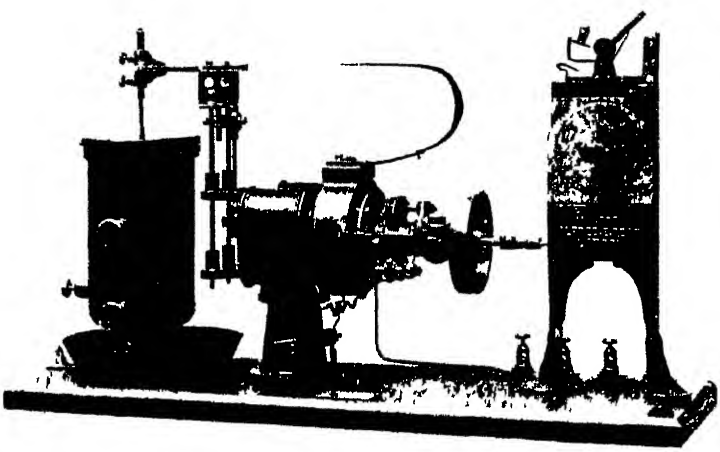


Fig. 69—Plunger Interrupter with Tachymeter

armature is moved by attraction of the core, those points are separated and the circuit is thus broken, then, when demagnetisation in turn occurs, the armature is returned by its spring to its original position, the circuit is completed and the cycle of operations recommences. The action is precisely similar to that of a trembler or hammer of an electric bell

Regulation of the various tension screws should be attended to, and the platinum contacts kept always in good order, to insure full efficiency in working

For modern X-ray work the vibrating interrupter is, at its best, however, far from efficient, and, in view of the very portable forms of motor mercury interrupters now avail-

able, this type of break may be considered as practically obsolete

2 (*a*) The **dipper** break makes and breaks contact by means of a metallic rod or segment alternately dipping into, and being withdrawn from, a reservoir of mercury, from which a connection passes to complete the circuit

There are two main designs of this type of break, one with a **perpendicular** dipper and the other **rotary**, each being driven

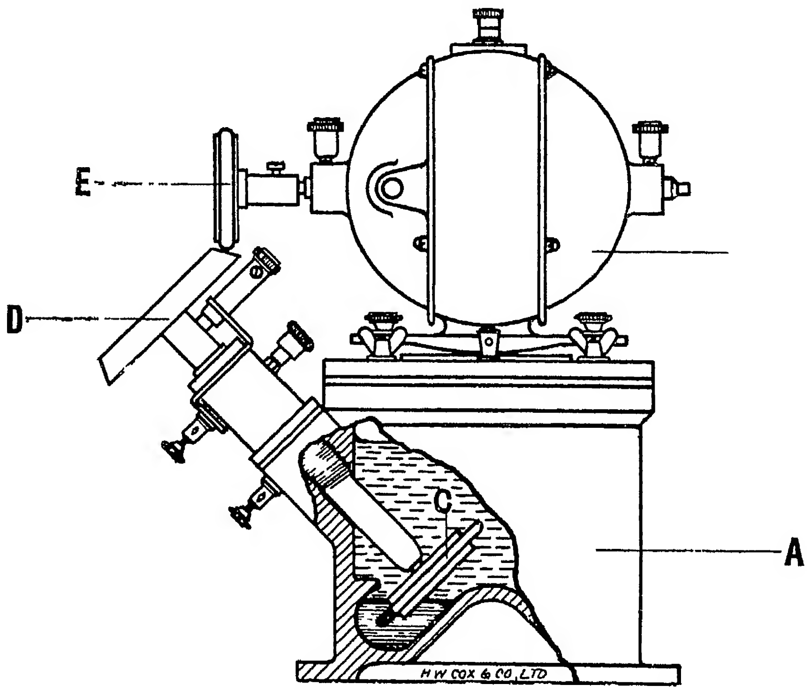


Fig 70 —Diagram of Rotary Dipper Interrupter

by a small motor on a circuit independent of the circuit of supply to the coil

Fig 69 will recall the appearance of the former, and Fig 70 that of the latter, but, although marking a considerable advance on the vibratory interrupter, those types have in turn been superseded by later types

A few such interrupters are still in use in treatment outfits, and their operation will be found discussed in earlier editions of this work, but the only design meriting detailed description now is the **centrifugal** type In that type of interrupter, represented in Fig 71, the mercury container is rotated rapidly,

and the mercury by centrifugal action is forced into a ring lining its inside surface There it comes in contact with a disc of insulating material carrying metal segments

As the disc revolves on its axis—eccentric to the container—the metal segments dip into and emerge from the mercury, making a rapid succession of makes and breaks This makes excellent contact, the duration of which may be varied by altering the depth of the revolving disc There is no churning of the mercury as in jet-formation, and the oxide inevitably formed in action is separated from the mercury by centrifugal action, so that cleaning is not called for frequently In the container, in addition to the mercury, is put a small quantity of liquid dielectric, such as paraffin oil This liquid being lighter than the mercury forms a layer on the surface of the latter, and this causes the arcing which invariably occurs at the break of the current to be rapidly quenched In this way the rapidity of interruption of the current, and consequently the inductive effect, is considerably increased.

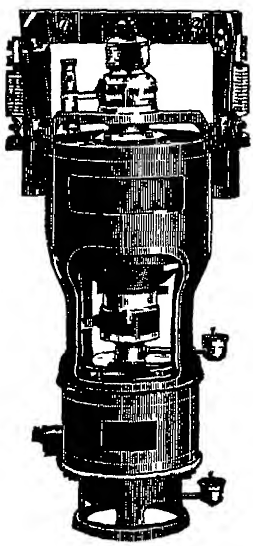


Fig 71—Centrifugal Interrupter

(*b*) The **turbine or jet** type of **break** has an action indicated somewhat by its name Fig 72 serves well to illustrate the mode of action of such breaks The mercury container (A) is there shewn separated from the working parts as if for cleaning When the break is set in motion, jets of mercury are by centrifugal action propelled radially from the central cone (E) through the orifices (B), and make contact with sectors of metal (C), which are carried on a cover of insulating material and connected to the terminals of the break By this means the mercury jets and connecting column of mercury bridge the gap between the sectors and thereby complete the primary circuit

The succession of makes and breaks is obtained by the rotary motion of the central stem carrying the radial jets with it Speed, and rate of interruption, can be directly regulated by altering the current sent to the driving motor. The metal sectors can be varied in number to secure a similar regulation, and these sectors are further made of a triangular shape, so

that vertical adjustment may vary the width of metal exposed to the jet, and consequently the duration of contact

The dielectric in this type of break is usually gas—ordinary coal gas being found to quench the arc very effectively

All interrupters employing gas as dielectric are fitted with inlet and outlet taps, and should on no account be used unless filled with gas To ensure this the inlet tap should remain connected with the supply and, before use each day, the outlet should be opened and gas allowed to pass until, when ignited at the outlet, it burns with a yellow flame indicating complete displacement of air

If coal gas be not obtainable, *ether vapour* may be employed as a substitute About one dram of ether is placed for this purpose on the surface of the mercury in the container The

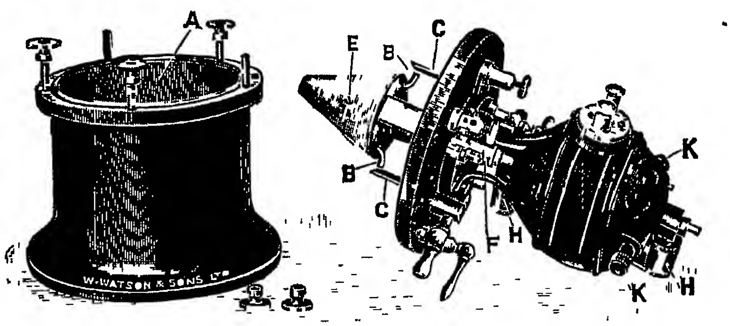


FIG 72 —MERCURY-JET INTERRUPTER.

interrupter is then run for a few seconds with a weak current and with both gas taps open The heat generated will vaporise the ether and the taps may then be closed. A gas bag should later be connected to one of the taps, and the tap opened so as to maintain a more even pressure as the ether vapour expands The mercury will require cleaning about once weekly

In the event of an *explosion* occurring in the container the pressure will release a safety valve arranged on the top of the container, and these *safety valves* should be tested occasionally to ensure that they are in working order.

With this type of break at rest there is obviated a danger which existed in the dipper type, namely, a risk of the continuous current being accidentally passed direct to the coil This cannot occur since the jet by which the contact is made is not formed until a fair speed of rotation is attained.

A high rate of interruption may be obtained with such a break, and heavier currents may be used than with the older types. The earlier breaks of the jet type were somewhat easily put out of order, and required frequent cleaning, which was a difficult and dirty process. Recent forms are simpler in construction, more easy to clean when clogged, and with the gas dielectric cleaning is seldom necessary.

In some early forms electro-magnets are situated on the cover of the instrument, and through the coils of these the current passes before entering the interrupting mechanism on its way to the primary of the induction coil. This has a disadvantage, since the rate of interruption cannot be varied independent of the strength of current supplied to the coil, or *vice versa*, and later designs have the motor winding independent of the break circuit, so that its speed may be varied independently, as in the arrangement shewn in Fig. 72. In that design the motor is built on the top of the interrupter and the axles are continuous, so that the whole moving parts remain in their relative positions when removed from the container (A).

Other similar interrupters, as in Fig. 73, have the motor mounted to one side of the main part of the interrupter, and a belt drive is interposed. This arrangement facilitates efficient insulation of the motor circuit from the main circuit, and it is specially convenient for attachment of a *mechanical rectifier*, which addition may be seen in Fig. 73 and found explained in the notes adjoining that figure.

Many interrupters are now adapted for use with **alternating current** by provision of a special motor designed to work synchronously with the periodicity of the current. The break may transmit only the impulses in one direction, while arresting, or diverting, those in the other, thus producing an interrupted unidirectional current suitable for supply to an ordinary induction coil, or with a specially constructed coil breaks are made to utilise both phases of the current. Care must be taken, however, that a suitable coil be used, as there is no possibility of varying the speed of the motor, that being determined by the period of the current, and the interruptions necessarily timed to coincide with the peak of each alternating wave. In earlier forms, the synchronicity was apt occasionally to fail, whereby the polarity of the resultant current might become reversed, and the irregular rays thus produced in an X-ray tube spoil an exposure for radiographic purposes. With modern interrupters

this difficulty has been successfully overcome, and it is possible with safety and efficiency to employ alternating current of which the periodicity is between 40 and 60, but synchronism cannot be assured when the periodicity exceeds 60

The **Moto-Magnetic Interrupter** (illustrated in Fig 65) is an interesting and useful device It is driven by a star-shaped magnet of soft iron, which is mounted on the upper end of the jet shaft This is rotated by influence of the successive magnetisations and demagnetisations of the core of the induction coil, opposite the end of which the instrument is set The jet portion is similar in design to that shewn in Fig 72, and the

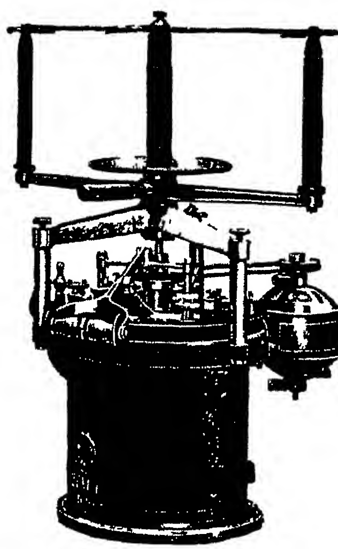


Fig 73—Mercury-jet Interrupter with Mechanical Rectifier

dielectric is coal gas The spindle is set revolving by hand to produce the first magnetisation of the core of the coil, after which the action is automatic so long as the current is switched on

For portability this design is decidedly valuable, although its range of usefulness is naturally limited by its size and construction

Mechanical Rectifiers.—In discussing *inverse current* in the latter sections of Chapter II (page 57), reference was made to the use of mechanical rectifiers in the secondary circuit for suppression of inverse current created by the high-tension generator

These rectifiers are fitted on many modern motor-driven

interrupters, and for ordinary purposes, certainly with currents up to 12 milliamperes, they form the most convenient and effective method of achieving that object Fig 73 shews a convenient arrangement of such a rectifier, the lateral mounting of the motor permitting attachment of the rectifier direct to the interrupter spindle Otherwise the arrangement becomes very high and accurate alignment of the bearings difficult

The rectifier consists essentially of a set of radial arms, carried at the upper end of a spindle, the rotation of which brings the ends of the arms successively into proximity to two opposite ball or plate terminals fixed in position and connected in the high-tension circuit

Fig 74 shews in diagram the arrangement of the connections,

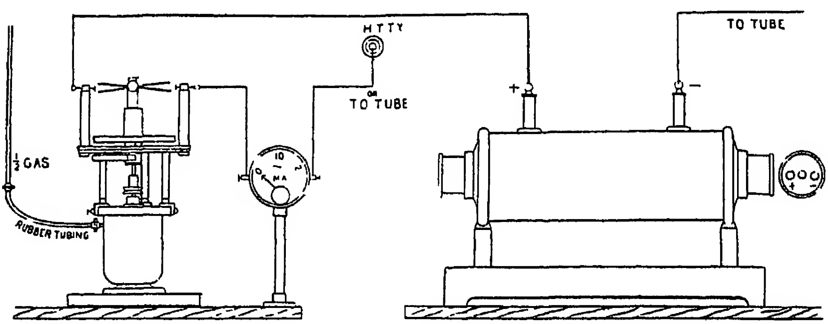


Fig 74—H T Connections of Coil and Interrupter with Mechanical Rectifier

and in Fig 86 the connections of a portable outfit will be seen as set up for operation

The position of the high-tension terminals relative to the interrupter contacts is adjustable by means of the handle seen to the left hand in Fig 73, and when adjusted the position is secured by means of a set screw By setting the terminals, T_1 and T_2 in Fig 75, so that one pair of radial arms, A B, bridges the gap between them at or near the moment of break of the primary circuit in the interrupter, the high-tension secondary current generated at that moment is able to pass by sparking from T_1 and T_2 to A and B, or *vice versa* At the succeeding moment of make in the primary the radial arms in their rotation will have reached a position, A^1 B^1, too far removed from the terminals for the secondary current to pass.

The gap in the secondary circuit is thus made and closed synchronously with the make and break of the primary circuit,

and in this way inverse current is eliminated Adjustment may be carried out while the interrupter is running. Correctly adjusted, the sparking which takes place between the radial arms and the fixed contact pieces should be confined to the length of the latter, if out of adjustment the sparking will be drawn out, either to meet the approaching arm or to follow it In the former case, the lateral contact pieces should be rotated in a backward direction (relative to the rotation of the arms), in the latter case they should be advanced, in either case the aim being to reduce the sparking to a minimum. This arrangement has a possible disadvantage in bringing the interrupter, which is in the primary circuit, extremely close to the high-tension secondary circuit, but, with suitable precautions regarding insulation and disposition of the various parts,

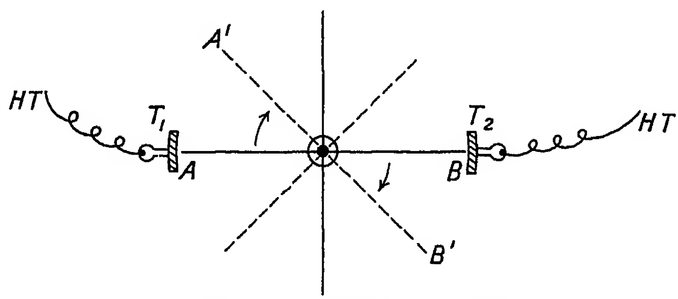


Fig 75 —Diagram of Mechanical Rectifier.

rectification can by this means be effected conveniently and without danger to the apparatus

The limit of its effectiveness is reached when high-tension current produces sparking sufficient to maintain an almost continuous arc between the terminal contacts and the rotating arms Within reasonable dimensions of moving parts this limit is reached with 12 milliamperes of current passing, but within that fairly wide limit mechanical rectifiers work extremely well and are to be recommended in preference to valve-tubes

3 **Electrolytic Interrupters or Breaks,** commonly known as Wehnelt breaks, from the name of their originator, have been extensively used as specially suitable for the heavier currents desirable for rapid radiographic work With these breaks a very rapid rate of interruption can be obtained (as high as 1,500 to 2,000 per second), and they are capable of transmitting very heavy currents. For such work, however, this type of interrupter has been largely superseded by the high-tension

transformer, which is capable of giving high intensities suitable for rapid radiography

The electrolytic interrupter cannot be used efficiently on a coil designed for use with a mercury break, but requires for successful work a primary with fewer turns in its winding and less iron in its core.

As the name indicates, these breaks depend partly upon the electrolytic action of a current passing between electrodes immersed in a liquid. If one electrode, the anode, be of very small area, the bubbles of gas formed tend to collect on it, and

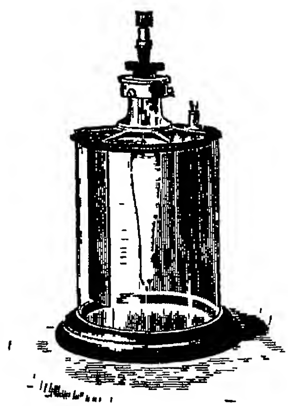


Fig. 76—Electrolytic Interrupter

Fig 77—Adjustable Anode

thus interrupt the continuous passage of the current, then almost instantaneously these are dissipated, and the current is again free to pass Due to the concentration of the current to the small area of the anode, considerable heat is developed and steam is formed in addition to the gas This steam is immediately recondensed by the surrounding fluid, and so appears on the anode only as instantaneous films or bubbles A regular succession of accumulation and dissipation of bubbles renders in this manner the current passed through the cell intermittent in character, and the periodicity so obtained is much more rapid than with any form of mechanical interrupter in use In

practice, the electrode of small area is composed of platinum, while the kathode consists of a lead plate of large area

Dilute sulphuric acid of density 1,200 is commonly used, though other fluids have been suggested as more suitable for certain purposes

The usual arrangement of the simplest kind, as shewn in Fig 76, consists of a large-sized glass cell, having immersed in the fluid a cylinder of porcelain from the bottom end of which a platinum wire projects, and a kathode in the form of a sheet of lead of suitable size The length of platinum wire which projects from the anode may be adjusted by a screw at the upper end, as seen in Fig 77 The amount of current passed

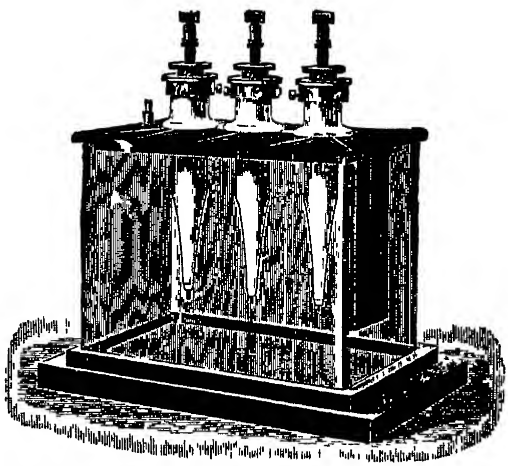


FIG. 78—TRIPLE WEHNELT INTERRUPTER, WITH LEAD COVER

depends directly upon the amount of platinum exposed, the rate of interruption varies inversely

The triple type, with parallel connections, illustrated in Fig 78, is now generally used, as it permits a much wider range of adjustment and regulation (in combination with the primary winding of the induction coil) than the single type just described

With electrolytic breaks the frequency of interruption will vary according to the voltage of the supply, higher voltages producing more rapid interruption By exposing a larger area of the platinum anode to the fluid the rate of interruption is reduced, and by exposing less the rate is accelerated.

For working with this form of break, as already mentioned, an induction coil with short primary winding should be employed, since the self-induction of longer primaries prevents

the rapid make of the current upon which the efficiency of this type of interrupter depends The condenser of the coil should in all cases with these breaks be put out of circuit

An efficient valve-tube capable of withstanding the passage of heavy currents must be included in the circuit, as there is a large amount of inverse current passed by all electrolytic interrupters, and obviously a mechanical rectifier cannot be employed with an interrupter of automatic character

In action, and especially with heavy currents of high voltage, electrolytic breaks are very noisy, so the whole cell and attachments should be cased in felt to deaden the sound, and the break should be kept in a separate closed room where possible

If the liquid is slightly warm the break acts better, but with heavy work the electrolyte becomes overheated Operation of the break is thereby embarrassed, and later stopped A cell of large capacity should therefore be employed to delay the heating effect, and the cell should be set into a larger vessel containing cold water, or should be surrounded by a spiral pipe with a circulation of cold water through it, if continuous heavy work be expected.

For use with currents of small quantity and low potential, as from batteries, these breaks are unsuitable.

They require for efficient working a current at a voltage of 40 volts or more, they will not work under 30, nor efficiently over 140, and work best between 60 and 80 volts With a current below 10 or 15 amperes, ordinary electrolysis merely occurs; with a current over 40 amperes the polarisation increases to such an extent that the current almost ceases and the anode becomes white hot, hisses and disintegrates in the liquid For heavier discharges than 20 or 30 amperes, as for very rapid radiography, two or more anodes are coupled in parallel, each transmitting 15 to 20 amperes

It is important that an electrolytic interrupter should be connected correctly, the **platinum to the positive pole** of the source If connected otherwise, the platinum will gradually dissolve, or possibly fuse if thin, and the coil will not act properly. If the direction of current be correct, the sparks in the interrupter have a red colour; if wrong, they have a blue colour Litmus-paper will, of course, give the necessary indication before connection is made, the positive pole making a red stain on the moist paper, as described in the section on the charging of accumulators

Electrolytic interrupters are simple and cheap, and are very efficient under specified conditions They are the most rapid of all breaks, and can transmit more current than any other type, though this latter advantage becomes less marked as other interrupters, and coils to suit, steadily improve.

They require practically no cleaning and very little attention, but they are noisy, give off acid fumes, and are liable to stop when the electrolyte becomes overheated It must be re-

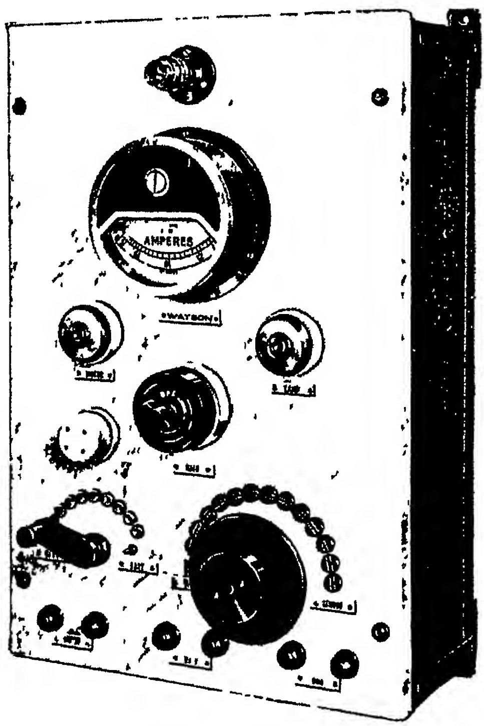


Fig. 79 —Wall Switchboard

membered, also, that they consume more current for a given output than a mercury interrupter

Electrolytic interrupters are used more commonly on the Continent, in conjunction with coils specially made to suit them The chief check to their use here has hitherto been the heavy mortality amongst tubes, most of which could stand the heavy current transmitted for a very brief period

Modern tubes are designed to withstand much heavier current, so that the use of those interrupters may be extended.

A modified form, known as the Simon or Caldwell interrupter, may be used also with alternating current

In this form both electrodes are of lead, and one is surrounded by a porcelain cylinder pierced by a number of small holes, at which the interrupting bubbles of gas are produced

This type gives no control over the current, but the inverse current is said to be smaller

In a further modification—the Caldwell-Swinton pattern—the cylinder is pierced with only one hole, by the regulation of which the current may be varied For higher voltages—say about 200 volts—the Simon type will probably give better results than the ordinary Wehnelt interrupter

With an alternating current the rate of interruption is equal to the frequency of the supply current, and is not variable at will

Switchboard for Induction Coil.—For the purpose of controlling the current supply to the coil outfit, some form of switchboard is required These vary in type and arrangement, according to the differing details of the outfits for the control of which they are designed The various switches and other items are usually assembled on a panel of marble, slate or other insulating material, and this panel may be mounted on the wall (Fig 79), or as a top to a table or trolley

The latter is the more convenient and more common arrangement, and that in the W O outfit, shewn in Fig 86, may be taken as an example of the usual arrangement

The items of that arrangement may be enumerated as the essential requirements of a switchboard for an ordinary induction coil outfit —

(*a*) A *rheostat* for regulating the current through the primary circuit

(*b*) An *ammeter* to measure the current thus passed

(*c*) A double-pole *fuse* to break the circuit automatically if the current accidentally exceeds a safe amount

(*d*) A double-pole *main switch* to switch on the supply to the board (A pilot lamp is usually wired across this as a signal to indicate when supply is connected)

(*e*) A single-pole *control switch* for the purpose of completing the coil circuit

(*f*) A *rheostat* in the interrupter motor circuit, which is separately wired to the main switch.

(*g*) A *switch* for the motor circuit

(*h*) A *fuse* for the motor circuit

For convenience of connection to the coil, interrupter and condenser, a set of terminals clearly labelled should be arranged on the switchboard, as along the bottom of the panel shewn in Fig 79, or along the back of the table or trolley frame, as shewn in Fig 86

On the trolley type there will further be a terminal for connection of the supply cable, and in either type there may further be provided terminals for the inclusion of a foot-switch

The plugs for both of those connections are shewn in

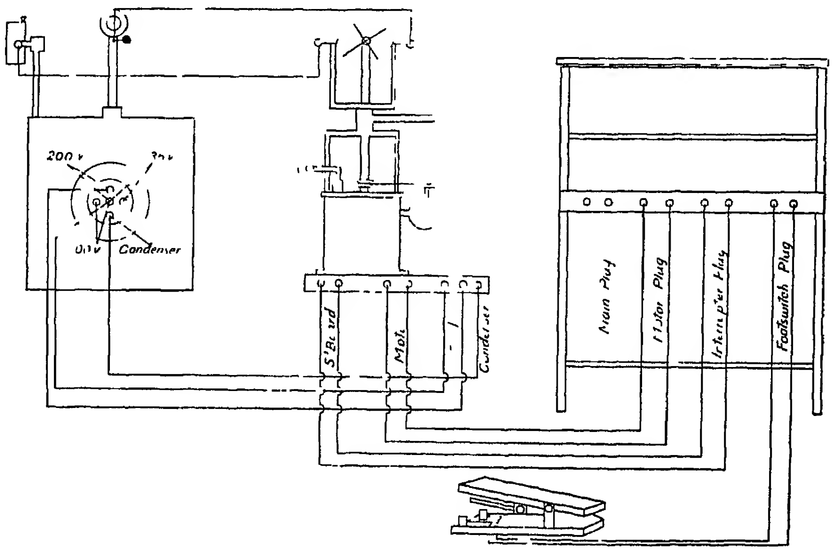


Fig. 80.—Electrical Connections of Primary Circuit

position, but without cables, in Fig 86, and the connections, with others, are shewn in diagramatic form in Fig 80

A *foot-switch* is seen connected in Fig 80, and is a very convenient accessory in an X-ray outfit, since it may be moved into any position in the room, and permits operation of the circuit by the foot of the operator whilst his hands and attention are engaged with the patient

A common form of foot-switch is shewn in Fig 81, where the spring release is plainly seen, as also two sets of terminals The second pair of terminals are for the purpose of connecting the pilot lamp across the foot-switch instead of across the main switch, as mentioned at (*d*) above

By this arrangement the pilot lamp is short-circuited and extinguished when the foot-switch tread is depressed for operation of the X-ray tube, and the room is thus made dark whilst X-ray operation continues This proves very convenient in radioscopy

The various rheostats and connections behind the switch-panel are more particularly the business of the electrical

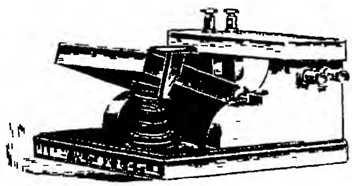


Fig 81 —FOOT-SWITCH

engineer, but it is well that the radiographer should understand the principles of their construction

The *main rheostat* consists of a number of coils of resistance wire, capable of taking the large current required without overheating.

The individual coils or resistance units (Fig 82) are behind the switch-panel (Fig 79), or beneath it (Fig 86), and are connected to the individual metal studs of the "volt-selector" on

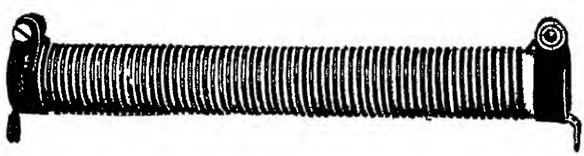


Fig 82.—RESISTANCE UNIT

the switchboard, as seen at the bottom right-hand corner of Fig 79

Usually those resistance units are arranged *in series*, so that any desired number may be included in the circuit, and the current reduced by their resistance accordingly

This is accomplished by rotation of a radial arm, so as to make contact with the appropriate stud of the volt-selector

The resistance may alternatively be arranged *in shunt*, in which case the units are connected differently, and as shewn in Fig. 83.

In the shunt form of rheostat, as soon as the main switch is losed current flows through the resistance coils from end to nd, and the potential gradually falls through the resistance.

From the connections shewn in Fig 83, it will be seen that ny required voltage up to the maximum may be applied to the oil circuit

With this form of rheostat it is an advantage to have a oltmeter on the switchboard to indicate the voltage being mployed The shunt arrangement has certain advantages, ut for most purposes a series rheostat suffices By means of

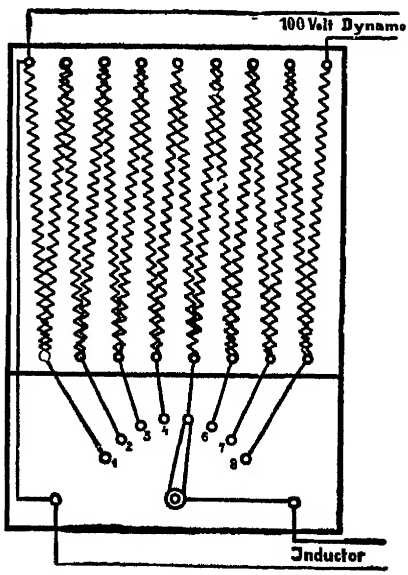


Fig 83—Diagram of Shunt Resistance, arranged in Circuit of 100-Volt E M F

urrent to the inductor or coil will decrease as the crank is moved over the studs towards the left Each of the sixteen spirally coiled wires may be taken to represent a fall in potential of $\frac{1}{16}$ of the maximum voltage, in this case 100 volts Thus the available voltage at any stud of the eight may be easily calculated The crank in figure makes contact with the fifth, at which the available voltage will be $(100 \times \frac{9}{16}) = 56$ volts

n additional switch, the rheostat may be made shunt or series s required

The *motor rheostat* is required for speed regulation, and is n series with the interrupter motor, which is usually of the series type and capable of considerable speed variation by djustment of the rheostat

Induction Coil Units.—The various constituents of a coil

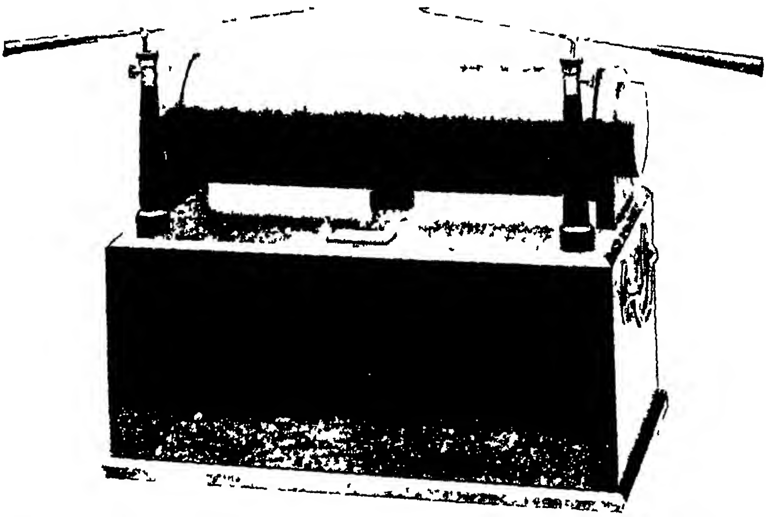


Fig. 84.—PORTABLE "WILSON" COIL UNIT, COMPLETE WITH INTERRUPTER IN CASE ONE-SIXTH FULL SIZE

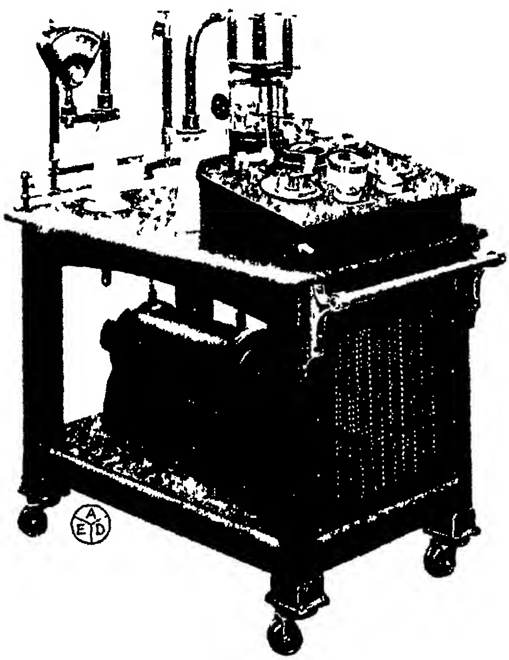


Fig. 85—HOSPITAL WARD PORTABLE UNIT

set or unit having been explained, their grouping under various conditions may be briefly considered, but individual circumstances and purpose must largely determine each case in practice

Portable units have already been referred to in Chapter III, where sources of supply are discussed, and a somewhat primitive arrangement with accumulators is shewn in Fig 51, on page 69 Except in improvised premises it is not often nowadays that such an arrangement will be called for, and the

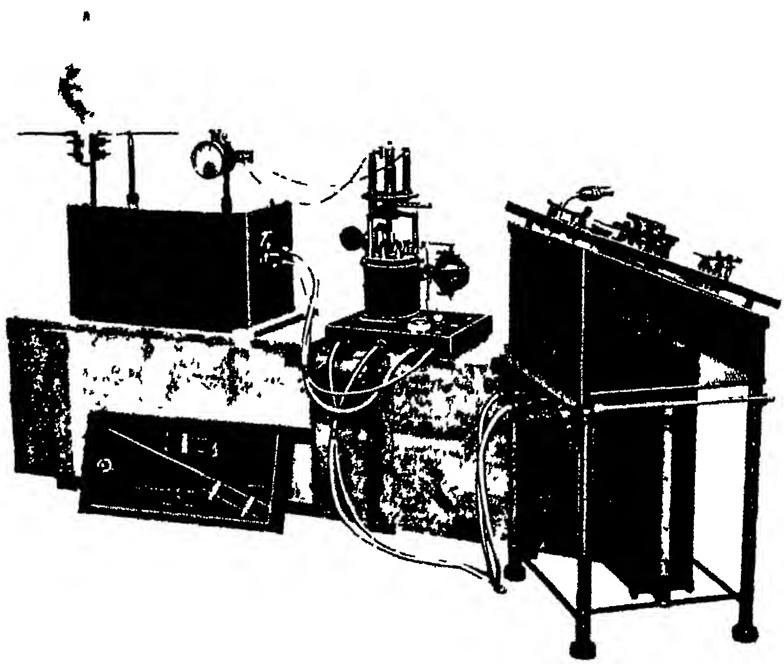


Fig 86—Coil, Interrupter and Control Unit (War Office Pattern)

utility of it is decidedly limited, but where the only source of supply is in the form of portable accumulators the best may have to be made of it

A very interesting unit, illustrated in Fig 84, was used largely during the war in wireless telegraphy, and from its compactness of design serves very usefully for portable outfits The primary and condenser of this unit are so arranged that the charging current is oscillatory in character, and so that a simple rotating disc interrupter with brush contacts is used, without necessity for oil, gas or spirit, as dielectric

The motor interrupter is fitted in the base of the coil, whilst the disc interrupter and the starting switch are at the back of the case forming the base In Fig 84 the unit is shewn at one sixth full size, from which may be formed some idea of its simplicity and portability

For *ward use*, as for fracture cases, in which movement of

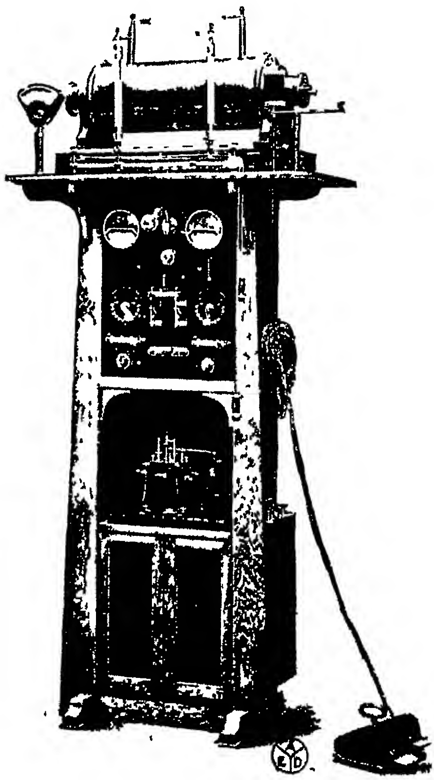


Fig. 87.—Pedestal Unit

the patient is prejudicial, or in which repeated screening may be desirable, a bedside unit may be very convenient, but this should, if possible, have current supplied from a conveniently placed generator, or from the supply mains of the building From the source of supply a long well insulated cable should lead to the unit, which may be moved into any convenient position for connection of high-tension leads to the X-ray tube

For *use in the field*, mobile units were mentioned on

page 76, and those may also serve for field hospitals, such as *casualty clearing stations*. A more efficient and convenient arrangement for the latter, however, is to transport the various items of the unit in separate cases, specially fitted for the purpose, and to supply a suitable set of connecting cables fitted with plugs, and plainly labelled to correspond with labelled sockets on the coil, interrupter and switchboard. To the latter another cable is led from a generating set, such as that shewn in Fig. 58, on page 76.

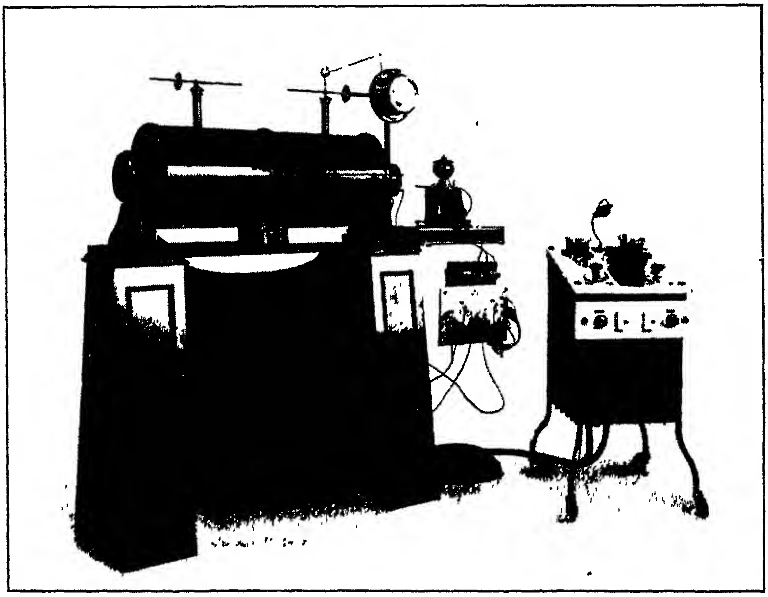


Fig. 88.—Coil Unit with Trolley Switchboard.

Such a unit is shewn in Fig. 86, and the connections are shewn in diagram in Fig. 80, on page 105.

For stationary hospitals the unit shewn in Fig. 86 might fulfil all ordinary requirements of radiography, but more convenient arrangements are usually made with more or less permanent connections between the different components. Those are mounted in suitable relative positions, according to the dimensions of the X-ray room and according to the nature of the work to be undertaken.

Where space is limited a pedestal unit, such as that shewn with foot-switch in Fig. 87, should prove very convenient. Otherwise the various items may be mounted on shelves

supported on wall brackets, but the assembled unit obviates any interference with the structure of the room, and may be readily moved at any time if alterations in the arrangement of the room be desired.

Where space is of less import, the addition of a trolley switchboard will be found a great convenience, and a unit such as that shewn in Fig. 88 will then be indicated.

The accessories of the high-tension circuit are not here considered, but their arrangement will be dealt with after the various parts have been described.

Interrupterless Transformers.

The principles of the transformation of low voltage altern-

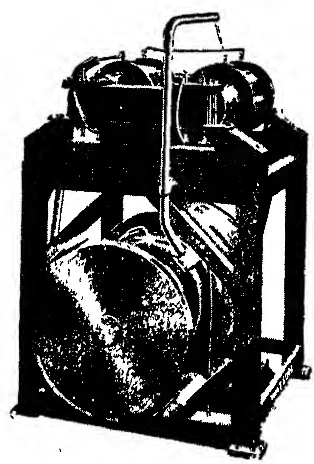


Fig. 89.—Interrupterless High-Tension Transformer—Dry Type.

ating current to higher voltages having already been considered (page 82), it only remains to describe the practical form of machine employed in X-ray work.

Owing to the very high voltages in the secondary circuit, similar precautions regarding insulation are required as were pointed out in connection with induction coils. The secondary winding is usually divided into two sections, fitted on two opposite sides of the rectangular stampings which form the closed magnetic circuit, and may be so noted at the top of Fig. 89. A point in the winding between the two sections is connected to the frame of the machine and thus to earth, so that no part of the high-tension circuit is at a potential

differing from that of earthed bodies by more than one-half the potential difference across the terminals of the machine. A further advantage of this arrangement is that the milliameter may be included in the circuit at that point and, being earthed, may be handled with impunity.

The primary is wound on a third limb of the rectangular core, the side furthest from the observer in Fig. 89. The machine shewn in that figure is designed for operation on a direct or continuous current supply, and, for the purpose of

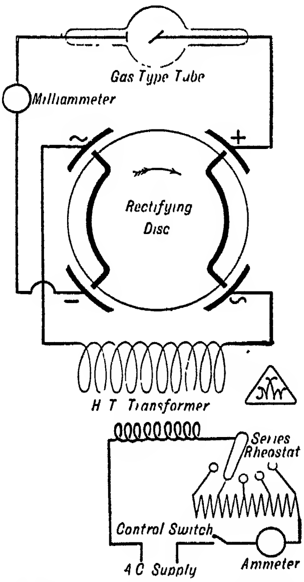


Fig. 90.—"GAS" TUBE AND RHEOSTAT CONTROL.

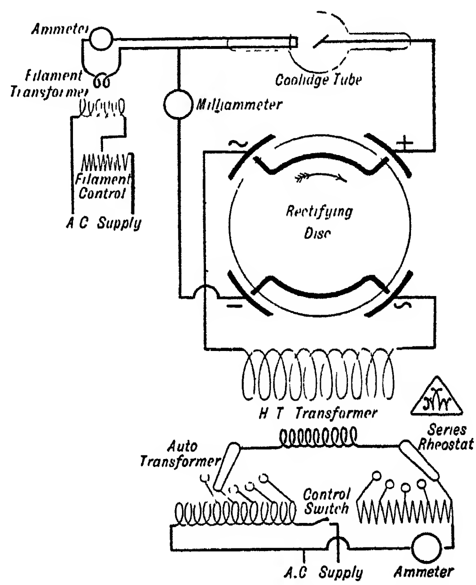


Fig. 90A.—COOLIDGE TUBE WITH AUTO AND RHEOSTAT CONTROL.

first converting that supply to alternating, carries a rotary converter, shewn at the back of the lower part of the figure.

This also drives the mechanical rectifier for the secondary current, which must be driven in synchronism with the alternating current produced. Where the main supply is already alternating in character, the rectifier is driven by a synchronous motor, of which this is the sole purpose, whilst the current from the mains is fed directly to the primary circuit by means of the controlling switchboard.

The **Mechanical Rectifier** in the secondary circuit of a transformer is somewhat similar in principle to that used on a coil interrupter, but, by automatically reversing the negative phase, it permits both phases of the current to be used.

The rectifier, driven synchronously with the [alternating current entering the primary of the transformer, in many designs consists of a disc of tough insulating material, on the edges of which are fastened two metal strips, which successively bridge the gaps between the terminals leading from the transformer and the terminals connecting to the X-ray tube. This disc may be seen in the front of the lower part of Fig. 89, and its rectifying action may be understood by reference to Figs. 90 and 90A, which shew the disc in two successive positions. A similar disc is shewn in Fig. 93.

From this it will be seen that if the disc is properly timed, the positive and negative phases of the high-tension alternating current will be sent through the X-ray tube in the same direction. It is claimed by makers that by suitably adjusting the lengths of the sectors and segments, only the higher voltage portions of the alternating current may be sent through the tube. The intervention of the spark-gap inherent in the action of the rectifier certainly has this beneficial tendency.

A similar rectifier is shewn in Fig. 92, whilst another form of rectifier is shewn in Fig. 91.

Frequency Reducers are added to many machines for the purpose of reducing the frequency of the impulses in the high-tension current. Those are in the form of current collectors, which operate on the primary side of the machine, being driven at half the speed of the synchronous motor. With this arrangement every second phase is eliminated, and only half the number of phases pass through the primary to induce a corresponding number of impulses in the secondary. A further reduction to one quarter may likewise be made.

Heating of the tube appears to be reduced by this device, and this may be of considerable advantage where a gas tube is being used continuously, as for radioscopy.

Transformers without Rectifiers may be used in conjunction with Coolidge tubes of the radiator type. As explained on page 52, inverse current is automatically suppressed by this type of tube, so that a mechanical rectifier may be dispensed with. These tubes are, however, limited in their operation, the limit in some being 10 milliamperes, in others 30 milliamperes, so that this advantage is limited to outfits of comparatively low power.

With the need for a mechanical rectifier removed, the interrupterless transformer unit operating from an A.C. supply

becomes extremely simple, as all rotating machinery is eliminated, and the filament of the tube may be heated from a special winding on the transformer.

The unit can therefore be made very compact in form and regulation made precise and easy in operation.

Oil Insulation has come into widespread use for transformers of high power. Formerly in this country, and still for trans-

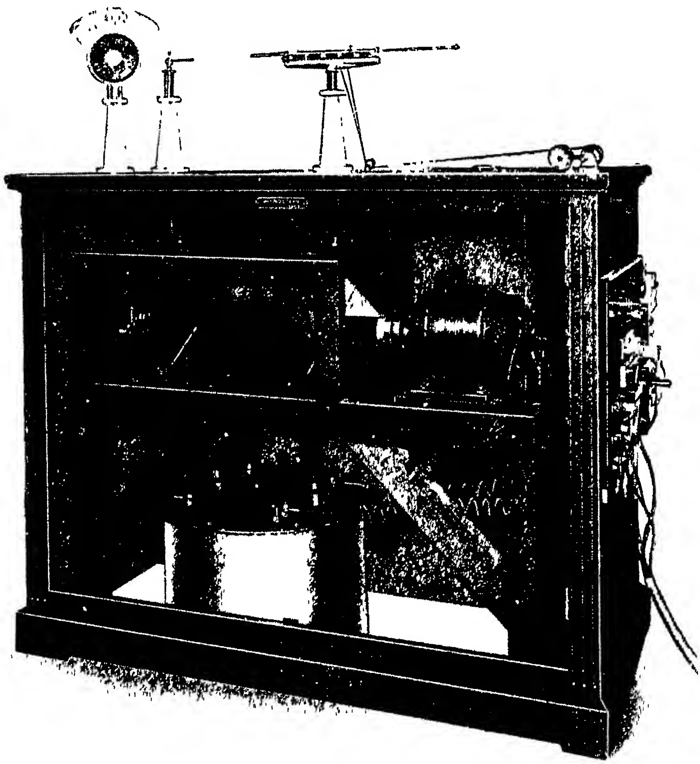


Fig. 91.—High-tension Transformer with Spindle-and-Points Rectifier.

formers of lower output, transformers were constructed with wax insulation of the secondary windings, as used in induction coils, and those are much more convenient to handle than the heavier oil immersed transformers.

For higher voltages and larger currents over continuous periods, however, the wax insulation presented difficulties overcome by the immersion of the whole transformer in oil contained in a steel tank. Fig. 92 shews, oil immersed, a similar transformer to that seen in dry form in Fig. 89. Oil

immersion has recently been extended to the whole of the high-tension circuit, including the X-ray tube. Oil is transparent to X rays, and this arrangement, where fixture of the X-ray tube is not a disadvantage, makes the whole X-ray generator self-contained and eliminates many of the high-tension difficulties experienced with X-ray outfits of the ordinary type.

Control of the Interrupterless Transformer may be similar in form to that described for the induction coil unit, but the employment of alternating current permits a second method of control, with very definite advantages in working with an incandescent-kathode tube.

(*a*) **Rheostat Control** may be exercised over the primary

Fig. 92.—Oil Immersed High-Tension Transfomer.

current, as shewn diagramatically in Fig. 90, in which case a trolley switchboard may conveniently be employed.

This will be similar to that described for a coil outfit, on page 104, but the items there included for control of the break motor will not be required. Fig. 93 shews a switch-table of this kind, and the switch-gear and starter for the synchronous motor of the rectifier (or rotary converter if supply be D C.) may be seen on the end of the transformer cabinet.

An additional item is necessary for this type of transformer in the form of a *polarity indicator and reverser*, since the direction of the secondary current in the X-ray tube will depend upon whether the positive or negative phase of the primary is picked up in starting the motor.

An alternative arrangement of these motor controls is seen

in Fig. 101 (page 127), where the starter, switch and polarity indicator and reverser are mounted on the panel or frame of the trolley switchboard.

As already explained, the voltage transformation in a high-tension transformer depends primarily upon the ratio between the number of turns in the primary winding and the number in the secondary.

For a given voltage in the primary of a machine, therefore, there may be expected a definite corresponding voltage in the secondary, and the function of a rheostat is to control, according

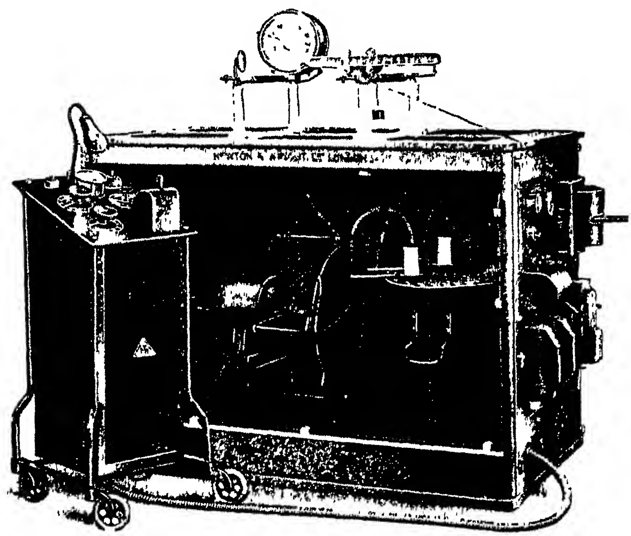


Fig. 93.—Rheostat Control of Interrupterless Transformer.

to requirements, the voltage applied to the primary. The voltage drop in the coils of the rheostat depends, however, upon the current passing through it, whilst the current taken by the primary of the transformer, and therefore passing through the connected rheostat, depends upon the current passing through the secondary circuit. Only so long, therefore, as the current passing through the X-ray tube might remain constant, could the secondary voltage corresponding to any setting of the rheostat control be relied upon, whereas alteration of the tube current will inevitably produce alteration of the secondary voltage, and compensating adjustment of the rheostat must be made to preserve the desired degree of pene-

tration of the resultant rays. With gas tubes the difficulty of maintaining their condition during operation has already been discussed, and their association with this type of transformer rather accentuates that difficulty.

With incandescent-kathode tubes the current through a tube may be regulated, and for a definite setting of the transformer rheostat a chart or table may be drawn up to shew the secondary voltages corresponding to various tube currents.

Thus, for a definite rheostat setting, **Tube Current** in milliamperes	gave **Tube Voltage** with *rheostat control* in Kilovolts	whilst similar currents gave **Tube Voltage** with *auto-transformer control* in Kilovolts
10	100	100
20	88	97
30	75	94
40	62	92
50	48	88
60	36	85
70	22	82
80	10	79

From the foregoing table it will be seen that the tube voltage decreases rapidly as the milliamperage increases, especially with rheostat control. This applies also to X-ray work with an induction coil to which the rheostat is the only form of control applicable, and the resultant difficulty is a decided disadvantage.

(*b*) **Auto-transformer Control** almost entirely overcomes the disadvantage, but the use of this is confined to alternating current. With alternating current the voltage may be changed by electro-magnetic induction, the induced voltage depending upon the number of turns in the secondary winding as compared with the number in the primary, so that if the primary be kept constant, and a number of tappings be provided at suitable points in the secondary, a series of pre-arranged voltages may be obtained at will. On those lines a step-down transformer of the ordinary kind might be used on the supply voltage, the control, or volt-selector, studs being connected to the tappings in the secondary to obtain the voltage required in the primary of the high-tension transformer.

The voltage thus derived would remain practically constant for all values of the current, and such an arrangement would be very efficient, as, unlike the rheostat, the windings may be made of low resistance, and in consequence practically no loss

of energy would occur. The arrangement known as the *auto-transformer* practically serves the same purpose and is cheaper to build, since for the same capacity less material is required. In the auto-transformer the primary and secondary windings are part of the same continuous wire, the primary voltage being applied across the whole winding and the secondary voltage obtained by tappings, as described and as shewn diagramatically in Fig. 94.

The auto-transformer acts much in the same way as the

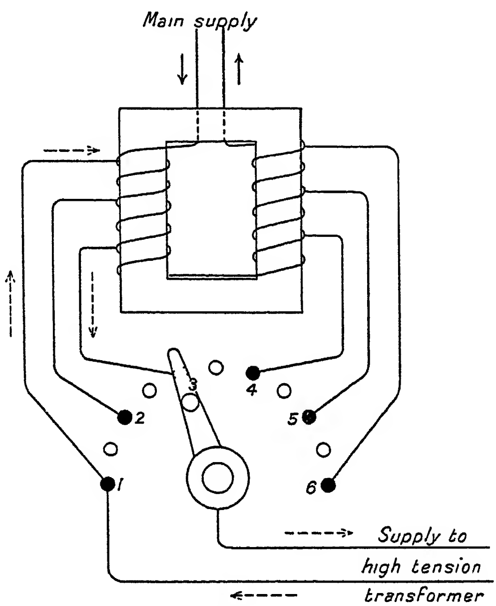


Fig. 94 —DIAGRAM OF AUTO-TRANSFORMER CONTROL.

ordinary transformer, but self-induction is operative instead of mutual induction.

There is, as mentioned above, little loss of energy in this method of control, and it is further to be preferred over a rheostat in that the high-tension voltage varies much less with changes in the tube current. In the table opposite, in the third column, appears a list of values of tube voltage for various tube currents at a given setting of the auto-transformer control, and by comparison of those with the corresponding values with a rheostat control the advantage of the auto-transformer control is obvious.

By its aid the operation of an incandescent-kathode tube is

made at once simple and precise, since it makes the regulation of the two factors of penetration and milliamperage more nearly independent.

One adjustment only is necessary for the precise determination of either factor; for penetration, adjustment of the auto-transformer control, and for milliamperage, adjustment of

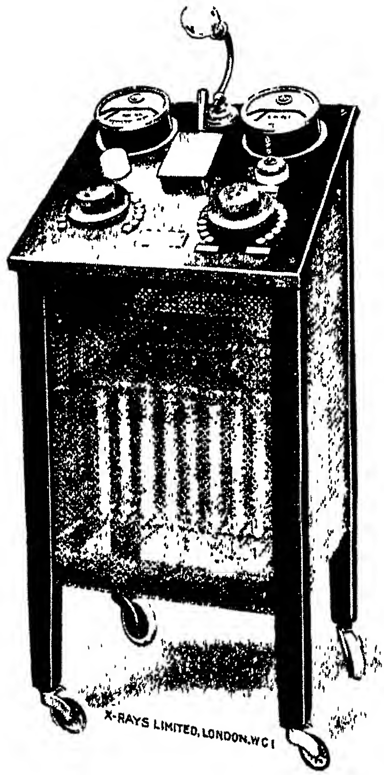


Fig. 95.—TROLLEY SWITCH-TABLE FOR INTERRUPTERLESS TRANSFORMER.

the filament heating current; whilst the settings for each of those can be definitely calibrated and registered in advance.

Unfortunately, this arrangement is not suitable for use with gas tubes, so that, even when an auto-transformer is fitted, most interrupterless transformers are fitted with a rheostat as well for alternative use.

In Fig. 95 may be seen the two sets of control studs, etc., for the alternative methods, whilst also on the panel are mounted a *kilovoltmeter*, which measures the secondary voltage (R.M.S.) applied across the tube, and a *milliammeter*, which indicates the

current passing through the tube. The voltmeter, though calibrated to measure the secondary voltage, is actually connected to the primary, since the ratio between the two is definite and fixed.

The instrument does not, however, indicate the peak voltage of the current, as does the spark-gap, but the R.M.S. voltage, a difference which it is important to remember. The

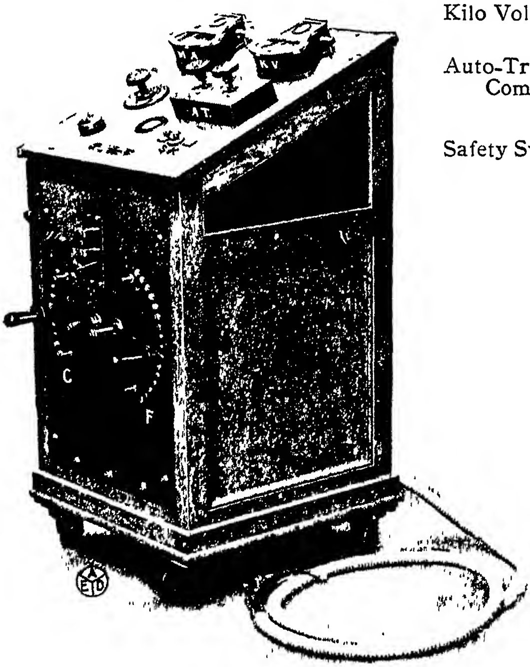


Fig. 95A.—Trolley Switch-table with Filament-heating Control.

meaning of this "root mean square" value is explained in the introductory notes (page 4), and the relationship to the peak voltage may be seen from the table on page 14.

The milliammeter, being connected in the secondary circuit, as explained previously, at a point which is at earth potential, may be safely placed upon the switchboard, but in some outfits it is mounted upon the transformer cabinet.

Where an incandescent-kathode tube is in regular use, it is a convenience to have the regulator of the filament-heating control also on the switch-table, and this may either be in-

corporated in the design of the table, as in Fig. 95A, or be attached to the frame subsequently.

Automatic Time Switch. Where it is desired to utilise the full power of a transformer outfit for radiography, or where the mechanical timing of short exposures may be practised, a time switch, although not essential, may be added to the control apparatus of the outfit. This is usually an arrangement whereby a bridging contact is set in motion, and after attaining considerable velocity passes between a pair of fixed contacts, completing the circuit between those whilst sweeping through

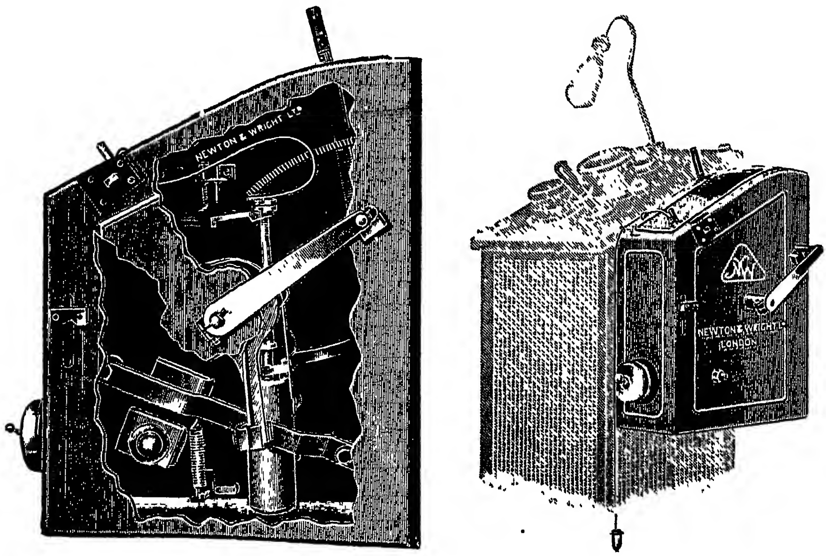


Fig. 96.—Automatic Time Switch.

between them. The duration of contact and resultant time of exposure is regulated by means of a dash-pot, which may be set so to arrest the movement of the bridging contact for the desired length of time. The switch shown in Fig. 96 is of this type, being set by means of a lever handle and released by sliding a knob or pulling a cord.

This may be set to make contact for periods from 8 seconds to $\frac{1}{80}$ second, the resultant X-ray exposure being presumably proportional. The accuracy of this presumption for the shortest exposures may be questioned, and reliance is not commonly placed now upon the sensationally short exposures at one time aimed at.

Interrupterless Transformer Units are more or less self-contained, unless for the switchboard, and that too may be mounted on the cabinet containing the transformer; and the various settings may be made very simple by means of numbered studs on each of the controls.

For *portable use* the advent of the self-rectifying radiator type of Coolidge tube has rendered possible the design of several interesting and valuable outfits.

For *ward use* compact and serviceable bedside units are available. After the type supplied for the American Army Medical Service during the war, many of those units are designed to supply secondary current at a fixed voltage, about 64,000

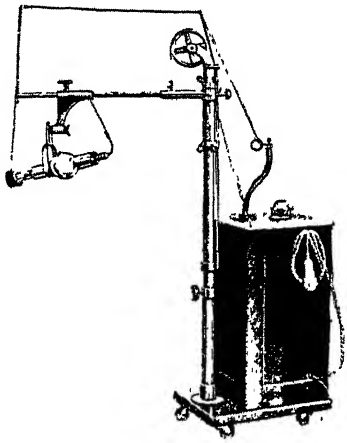


Fig. 97.—Bedside Unit with Interrupterless Transformer.

volts, equivalent to a 5 in. spark-gap between points, and at that voltage to supply current for the 10 milliampere radiator Coolidge tube. Thus arranged the operation of the unit becomes almost automatic, exposure being made by manipulation of a small switch fixed on a length of flexible cable, so that it may be held in the hand and operated from any position.

Such a unit is shewn in Fig. 97, along with an attached tube stand for the radiator tube. The foregoing type of unit carries in its fixed values certain disadvantages, as with such the length of exposure is the only factor variable at will. For a radiographer anxious to have more control over his results, the self-rectifying tube may be used with other units furnished with controls, such as that shewn in Fig. 98.

This includes an auto-transformer for regulation of potential

and a filament transformer for control of tube current, the same iron core being employed for the windings of those as for the high-tension transformer, thus rendering the whole machine very compact. By the meters can be measured the tube current and the potential across the tube (from 2½ in. to 5 in. equivalent spark-gap), and after setting the controls one switch operates the tube.

This unit might do good service also in a small consulting

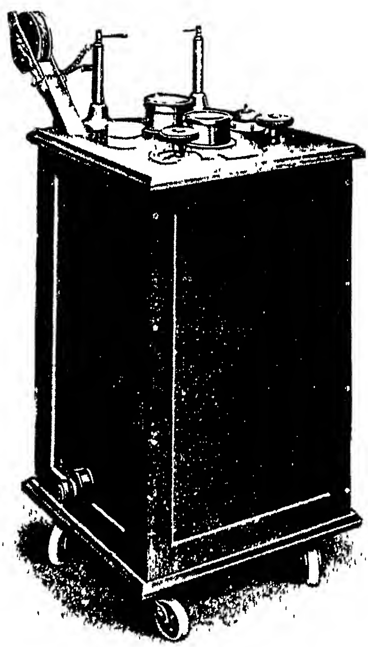


Fig. 98.—Bedside Unit with Controls.

room; or a *stationary unit* after the same idea, as shewn in Fig. 99, may be so used. This latter unit has an auto-transformer for control of voltage and a separate transformer, seen at top of the cabinet in the figure, for control of current to the heating filament of the kathode. This latter is regulated by a sliding resistance (seen on the switchboard), otherwise regulation of the machine is by induction.

With this it is claimed that a radiogram of any part of the body may be taken in one second, and under ordinary conditions and using double intensifying screens, this is found to be the case.

For the benefit of general practitioners, or for other radiographers as yet unfamiliar with the factors of penetration and exposure appropriate for different parts of the body, an ingenious "technique director" is added to the switchboard of the unit illustrated. This is shewn in Fig. 100, and consists

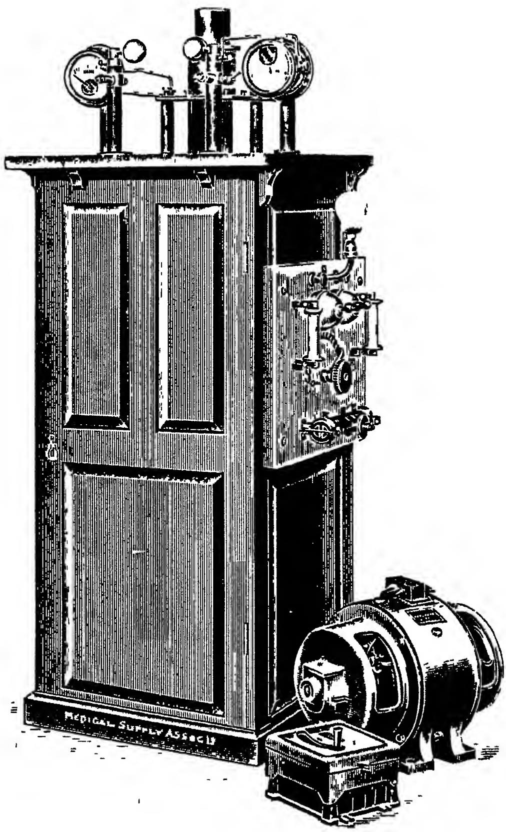


Fig. 99. -INTERRUPTERLESS TRANSFORMER UNIT FOR SMALL CONSULTING ROOM.

of a rotating disc on which, opposite each part of the body, is charted the kilovolts, milliamperes, time and distance requisite for a correct exposure of that part. Thus, for occasional work on the part of a practitioner not making radiography a special study, this unit may be useful and convenient.

On the switchboard, as shewn in figure, may be fitted a time switch for automatic time exposures.

Stationary Units will, as a rule, be desired of higher power

than the foregoing, so as to undertake all classes of work, and the nature and amount of that work will dictate the choice of a unit.

In design all are very similar, and the main choice to be made is in power rating.

Commercially, machines are usually rated according to kilovolt-amperes of output—written K.V.A.—a favourite power

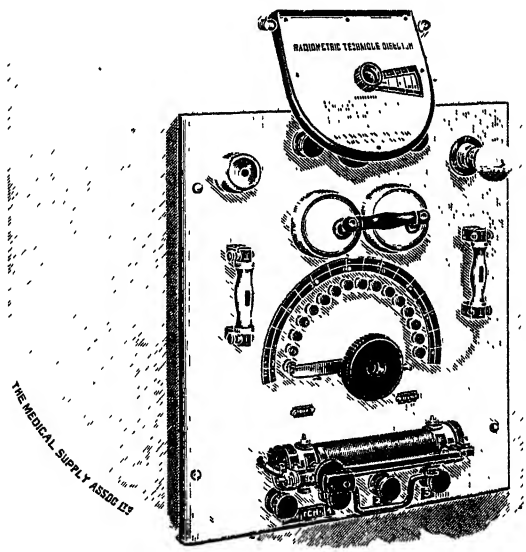


Fig. 100.—SWITCHBOARD OF UNIT SHEWN IN FIG. 99.

for general purposes being 10 K.V.A. This should deliver through a medium tube about 100 milliamperes; a 5 K.V.A. should similarly pass about 50. If the machine is used with a harder tube, of course the milliamperage through the tube will fall proportionately.

Considerable confusion exists regarding the power of high-tension transformers, as already mentioned regarding induction coils (page 88), and this is particularly unfortunate when

transformers of different type are under comparison. From the radiographer's point of view this need not exist if he will insist upon quotations of performance in terms of his actual requirements. As already stated regarding coils, the standard of rating should be the capacity of a transformer unit to produce X rays of the desired quality, and quotation should be in terms of milliamperes of current passed through an X-ray tube of stated hardness whilst operating upon a standard supply. For any particular installation the supply should naturally be that available at the site of the installation, and the tube hardness that requisite for the class of work undertaken.

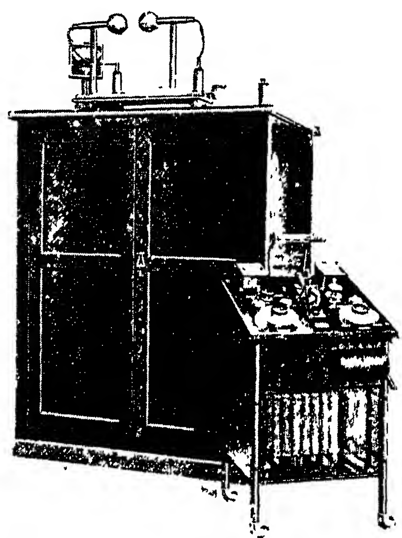


Fig. 101.—Interrupterless Transformer Unit of Universal Type (10 K.V.A.).

For comparison of induction coil units and interrupterless transformers this does not furnish a final standard, as the high-tension current generated in the two machines differs in nature and in productivity of X-radiation, as explained on page 84; so that actual radiation effects would require measurement to institute a final basis of comparison.

For comparison of machines of the same type, however, the standard is sufficiently precise and accurate; certainly much more so than mere quotations of electrical efficiency, which may be very misleading and beyond the power of the radiographer to verify even if understood.

A standard unit of one type is shewn in Fig. 93, on page 117; another is illustrated in Fig. 101, where all the controls, in-

cluding the starting gear for the synchronous motor or rotary converter, are seen mounted upon the trolley switchboard.

Those units may be constructed for radiography only, or with higher output (necessitating reinforced insulation) to undertake deep therapy as well. For the higher power units, indeed for all transformers, it is essential to remember that supply mains are not in all cases capable of supplying the full power required for the heavier loads imposed on the machines. This point should be looked into, with the assistance of the engineer supplying the machine in consultation with the electrical supply authorities.

Accessory Apparatus

A few items of apparatus accessory to the high-tension generators and X-ray tubes, essential for production of X rays, have already been described in relation to those essential parts.

Thus, in Chapter I, are described various *instruments for measurement* of the quality and quantity of X-radiation produced; in Chapter II, in context with incandescent-kathode tubes, are described *controls for filament-heating* of those tubes; and in Chapter IV are described *switchboards* or *controls* necessary for the high-tension generators there dealt with, whilst some representative assembled *X-ray electrical units* suitable for various purposes are also illustrated and discussed.

The remaining items of accessory apparatus are more in the nature of alternative equipment, the necessity for which, and the type or pattern of which, will be decided by the nature of the work to be undertaken and (secondarily) by the accommodation available. Regarding most of those items, therefore, it is only possible to suggest typical specimens as suitable for specific purposes; the choice of precise type and detail of equipment must depend upon individual needs and individual tastes.

Fluorescent Screens are practically essential items in X-ray outfits, since they are necessary to reveal the X-ray effects directly to the eye of the observer. Those screens were originally made of a deposit of platino-cyanide of barium on suitable material—usually vellum—stretched on a light wooden frame, and the best screens are still made of that material; although the excessive cost of platinum has stimulated the production of other screens closely rivalling them.

The platino-cyanide is, when new, of a yellow colour with a greenish tint. This green tint becomes lost through prolonged exposure to X rays, and the yellow assumes gradually more of a brownish tint, in which condition fluorescence is considerably diminished.

With careful use this should not readily occur, and occasional exposure to daylight will delay the "tiring" of the salt considerably.

The less expensive screens are known as of the "white salt" or Willemite type, and, where cost is a primary consideration, the use of these is to be commended. They give a brilliantly illuminated field of a brilliant green colour, but definition with some is not quite so good as with platino-cyanide, and the after-glow lasts slightly longer. Where much work is being done, a white screen might profitably be used for routine work, and a platino-cyanide screen reserved for critical cases.

Screens should always be kept dry and cool; moisture will buckle and crack them, heat or pressure will cause the crystals to turn brown and become inactive.

To observe the image on a screen properly the observer must be in darkness, and it will be found of advantage to let the eyes become accustomed to the darkness for a little before an attempt is made to view the screen, the retina becoming thus more sensitive. Dark boxes, with a fluorescent screen at one end and an eye-shade opposite, termed *fluoroscopes*, are made for use in daylight, but these are inconvenient in use, and no serious work should be undertaken unless in a room capable of being darkened at will. Ten to fifteen minutes should be spent in the darkened room before attempting a critical screen examination; otherwise exposure will be unduly prolonged, and much valuable detail may be missed in the screen picture.

For diagnosis of gross lesions and localisation of foreign bodies, a screen examination may be all that is required; but a point may be mentioned here that will be further impressed later—namely, that negative evidence can rarely be relied on from **screen examination** alone, but **should be checked by a radiogram.** This latter may reveal finer points not discernible on the screen, and even fractures have, for want of this corroboration, been overlooked, the absence of displacement masking the actual lesion (see Fig. 173).

Screens are made in various sizes, and vary proportionately in price, but for general work a screen should be large enough

to include readily in one view the apices of both lungs of an adult person. A larger size than 15 in. by 12 in. will seldom, if ever, be wished for, and, having one such screen, there is no necessity for a smaller one, though the latter may be convenient at times for special situations. If a vertical screening stand, described below, be included in the outfit, its screen, 15 in. by 12 in. to 20 in. by 16 in., should be detachable and available for occasional separate use; in which case a screen of the ordinary size, 12 in. by 9 in., should be kept for ordinary use.

It is necessary to have the fluorescent side of the screen covered by a sheet of superleaded glass, which will protect the surface from injury, and further, and more important, protect the face of the observer from injurious effects of the radiation.

Metal handles to protect the hands while holding the screen are sometimes also attached to it, but where gloves are worn, as advised, this is superfluous.

Vertical Screening Stand.—Where frequent screen examinations are being made of patients in the vertical position, as in diagnosis of chest conditions or in observing progress of a bismuth meal, it is found convenient to have a screen mounted vertically and arranged so that it can easily be moved about in a vertical plane. Continued development in diagnostic methods, especially with bismuth meals, has caused this to become a most important item in the equipment of a modern consulting room. Fig. 102 shews a comparatively simple but efficient design, which secures synchronous movement of the X-ray tube with the screen when this is desired. The large metal shield provides protection for the observer, the screen being covered with lead glass; and a plate holder may readily be substituted for the screen should a radiogram be called for.

The details, for convenience of working, in this and similar models are too many to enumerate, and many workers have special additions or alterations made to suit their individual methods. Fig. 103 shews a still simpler arrangement, which represents probably the minimum requirements of vertical screening, and correspondingly may involve a minimum of expenditure and space.

In one of those models illustrated the main parts of the stand are of metal, which has been objected to on account of possible short-circuiting of the high-tension circuit and consequent injury, or at least alarm, to the patient. This is hardly fair

criticism, as ordinary care in insulation of tube and connections should render this impossible.

Several useful models in wood are available which minimise the supposed risk, but those are necessarily more expensive in manufacture. They are handsome pieces of apparatus, however, and here again there is plenty of scope for individual choice.

Sundry attempts have been made to combine a vertical

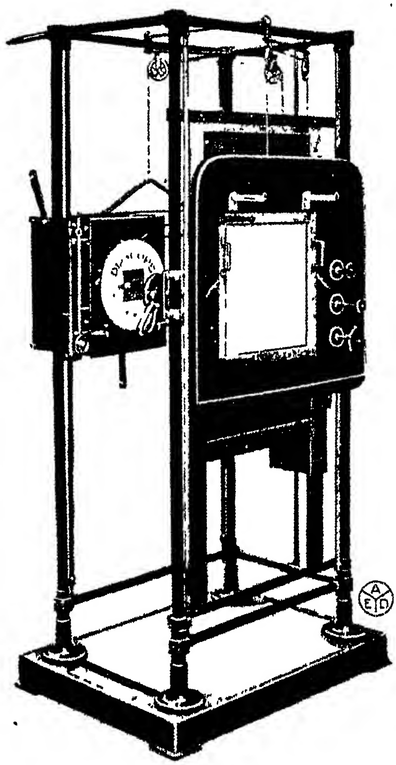


Fig. 102.—VERTICAL SCREENING STAND OR "DIASCOPE."

screening stand with the ordinary X-ray table, and for emergency purposes such a plan as that shewn on page 144 may serve. Special pieces of apparatus have been designed which may alternatively serve in the horizontal or vertical position, but so far the utility of those combinations has not been proven.

The **tube stand** for holding and permitting adjustment of the X-ray tube should, above all else, be **firm**. For this reason a stand is preferably somewhat massive, and should have a heavy base or foot. This base will be steadiest, on an ordinary

uneven floor, when arranged with three points of support. Many stands in use are much too flimsy and shaky, being designed apparently with a view to lightness, but this quality is of no practical importance, unless for portable apparatus.

Stands should all be made with a metal base for steadiness,

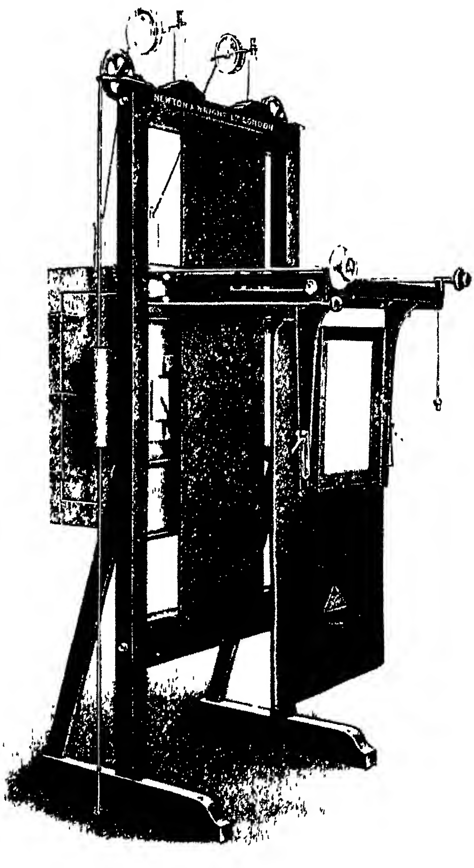


Fig. 103.—Vertical Screening Stand of Simple Type.

though the remainder may be of wood, thus avoiding risk of short-circuiting while making the stand more portable. With ordinary care, however, all-metal stands should be perfectly safe, and the mechanical details of those are so much more satisfactory that wooden stands may be considered obsolete, unless possibly for portable sets.

Fig. 104 shews two designs of metal tube stand; a heavier and more universal type is shewn in Fig. 105.

A stand should be of sufficient height for all possible purposes, and the means of adjustment should be simple, as otherwise stability may be interfered with. Bearing the same end in view, care should be taken in adjustment that the X-ray tube is kept always as near the supporting upright as may be compatible with the position desired. In this position a certain

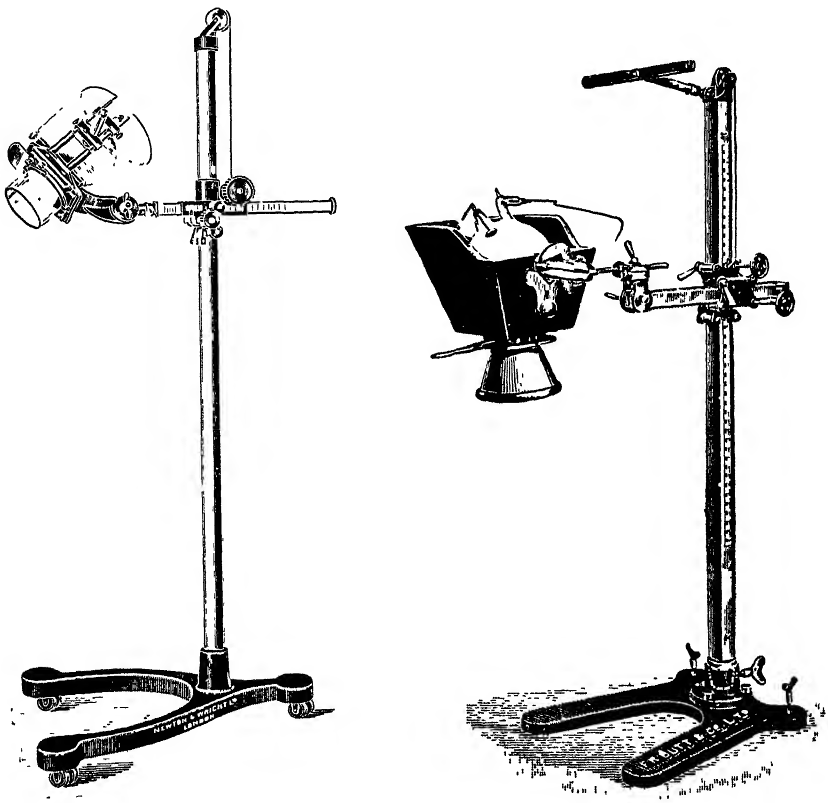


Fig. 104.—METAL TUBE STANDS WITH PARTIALLY PROTECTIVE TUBE SHIELDS.

amount of compression may be employed on the part being radiographed, provided that the stand is heavy enough to maintain stability.

For this purpose the tube shield may be fitted with *compressors* of various lengths and diameters, similar to those shewn in Fig. 104. Those serve as diaphragms to cut off undesirable radiation as well as compressors, both of which actions are discussed later in connection with X-ray tables (see page 146).

All recent stands are made with some form of *protecting*

enclosure for the tube, and this must be considered a vital necessity for the protection of the operator as well as of the patient. The protection may take the form of a superleaded glass shield, through which the action of a tube may be observed, as shewn in one stand in Fig. 104, and in Fig. 105, or similar glass may be shaped as an enclosing tube like that shewn in Fig. 37, on page 53. Other shields are made of wood lined

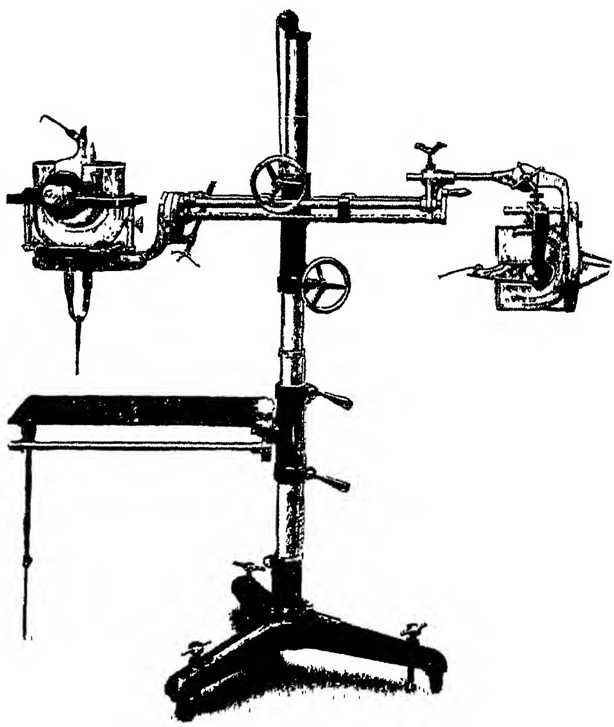


Fig. 105.—Heavy Metal Tube Stand.

with lead rubber, or of special compounds having insulating, as well as protective, properties. That shewn in the second stand in Fig. 104 is not sufficiently protective for all purposes; a more complete protection is provided by the interesting design shewn in Fig. 106.

This type, supplied to the War Office, was made to fit on the stand shewn in Fig. 105, and was designed to enclose the entire X-ray tube, a precaution of great importance with incandescent-kathode tubes. For such tubes the shield proved excellent.

It is an important point for accurate radiography, and equally in localisation, that the tube shield should have a convenient means for *centering the tube*, so that the target may be set in a definite central position that is fixed and may be reproduced at any time and with different tubes.

Where a standard make and size of tube is always employed, the reproduction of this position will be easy, as the tube clamps or carriers will remain set and will receive each tube into the same position.

Where different tubes are in use, however, with varying diameter of stems, it is necessary that the tube clamps should be adjustable and that means be provided for centering the

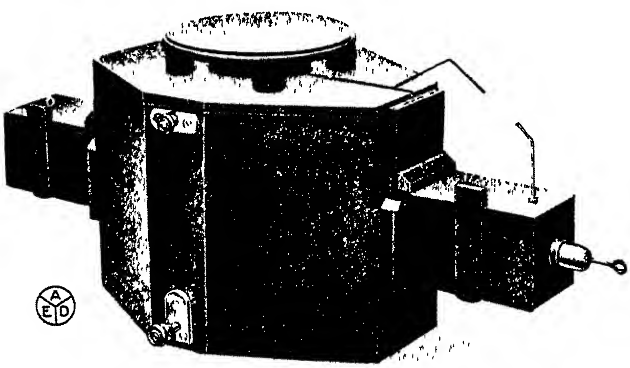


Fig. 106.—Tube Box for Incandescent-kathode Tube.

target of the tube. This is most conveniently done by means, of a sighting tube or hole in one or both sides of the shield. Such a tube may be seen projecting from one side of the rectangular tube box in Fig. 104; on the opposite side of the box will be a white spot or a hole exactly opposite the tube. Fig. 107, representing a tube carrier from an X-ray table, well illustrates the idea.

The tube should be so set that the target surface is bisected by the axis of the sight, and so that the line of the target surface bisects the circle of the sighting tube or hole, as shewn diagramatically in Fig. 108.

This setting insures the central position of the tube in the tube shield, and also defines its position vertically in relation to other parts. Further notes regarding tube setting will be

found in context with X-ray tables (on page 145), and its importance will be appreciated after reading the later notes on localisation, stereoscopy, and radiography in standard positions.

For **therapeutic purposes** protective arrangements are essen-

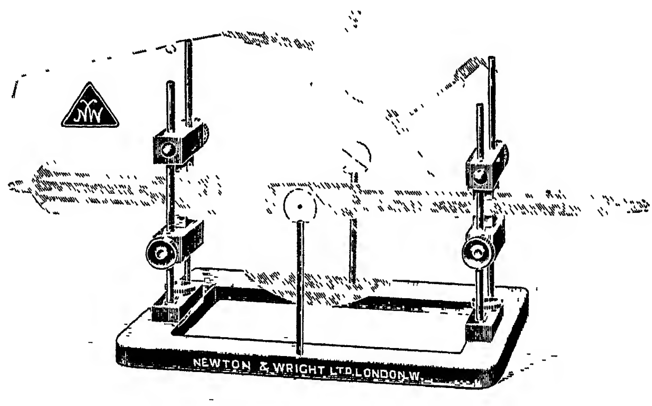


Fig. 107.—SIGHTS FOR CENTERING TUBE.

tial, especially in working with the very hard tubes employed in deep therapy. The stand should be adapted to carry, along with the tube shield for protection of the operator and of parts of the patient other than that on which the effect of the radiation is desired, a series of tubes or funnels of similar material and of varying diameter. The distal end of such a funnel being placed against the surface of the part under treatment, the length of the funnel will determine the distance of the antikathode from

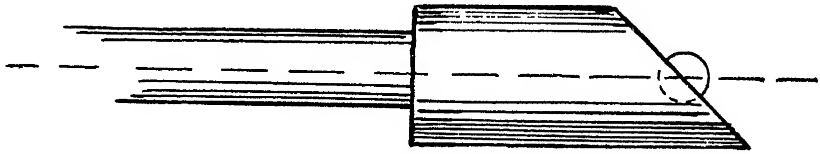


Fig. 108.—SETTING OF ANTIKATHODE OF TUBE IN TUBE BOX.

that surface, a most important point in estimating dosage, and by choice of a funnel of appropriate diameter a larger or smaller area may be exposed, while the surrounding tissues are protected. This replaced the earlier clumsy method of protection by sheet lead, and, the funnels being readily sterilisable, there is no objection to their repeated use.

Many different designs of stand are made, and the protective devices for the tube also vary, but the general idea is the same in all, and the foregoing notes should serve to indicate the main points demanding attention in selection.

The **table or couch** is a piece of apparatus of prime importance for convenience in X-ray work. The best tables for general use are those made with a **top of material transparent to the X rays,** while the X-ray tube is carried underneath in a suitable box or holder, which may traverse the full length and breadth of the table as well as allow adjustment perpendicularly. On such a table the patient may be placed in any suitable position, while the tube is moved vertically opposite the region desired to be examined. The fluorescent screen may meanwhile be placed above the patient, and a comprehensive screen examination made in a short time with a minimum of inconvenience to patient and operator. Then at any desired point the tube may be fixed, and a sensitive plate substituted for the screen if a radiogram be desired. The previous viewing by the screen insures finding on the plate precisely the part indicated.

For an inexperienced worker this will be found of great advantage, even although later he may choose to dispense with the preliminary screening in many cases and rely upon setting the tube above the patient as directed by anatomical landmarks and other indications.

For a time it was the accepted practice to arrange all tables with a *screen or plate carrier* above the table, and so linked with the tube box as to move in sychronism with it. Except for localisation purposes, however, such an arrangement is not now commonly added to a radiographic table, since the superstructure necessary is apt to interfere unduly with movement of the patient and convenience in manipulation. The principle of it, and its special usefulness, will be understood by reference to the special table shewn in Fig. 113 and described in the adjoining text.

In the absence of an attachment to the table, some arrangement must be made for carrying the screen or plate when working with the tube below the table.

Those are considered in a later chapter on "Photography," at page 180.

Many points of detail will naturally vary in different designs of radiographic tables, but the essentials are common to all.

The **main body** of the table consists of a strong wooden or metal frame supported at the four corners, leaving the full length free for traverse of the carriage bearing the X-ray tube and possibly the fluorescent screen. On this frame is carried a top of three-ply wood, firm enough to bear the weight of a heavy patient. This top should be uniformly transradiant; the presence of knots or flaws in the wood may cause considerable confusion in the interpretation of radiographic appearances.

Fig. 109, representing a portable table with folding canvas top, shews the usual arrangement of the **travelling carriage** carrying a tube box under the table, and moving on wheels or

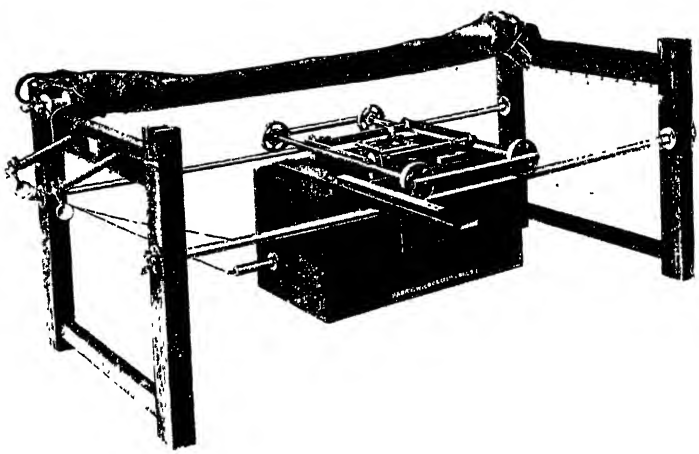


Fig. 109.—PORTABLE X-RAY TABLE SHEWING TUBE BOX.

rollers running along a horizontal guide on either side of the table. The **tube box** consists of a wooden box covered with lead the main essential here being *protection* of the operator and patient. The box has supports for the tube at either end, which are adjustable vertically and horizontally, so as to get the tube properly set and centred. One form of this arrangement is shewn in Fig. 107.

The box, with the tube, can be moved transversely to the table on small rollers resting on horizontal guides, forming part of the travelling carriage.

This transverse movement is controlled by a projecting arm, on which a scale is marked indicating the position of the tube. Thus it will be seen that the tube can be moved readily to any position within the borders of the table.

On the upper side of the box is situated centrally an adjustable **diaphragm**, the value of which will be explained later.

Such diaphragms may be of *iris* type, as commonly used in photographic cameras, or of *rectangular* type, consisting of four metal leaves heavily backed with lead and adjustable in opposite pairs by projecting handles, as shewn in Fig. 110. The latter form is preferable in this situation since, besides the dual adjustment, it permits the use of heavier metal with consequently greater protection.

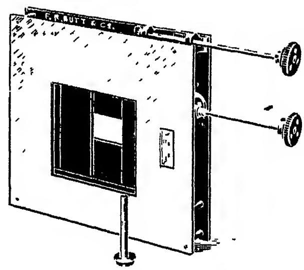


Fig. 110.—RECTANGULAR DIAPHRAGM.

Further protection of the operator should be furnished by provision of *aprons* or *shields* of lead rubber, or lead-lined wood, moving with the tube box and situated between that and

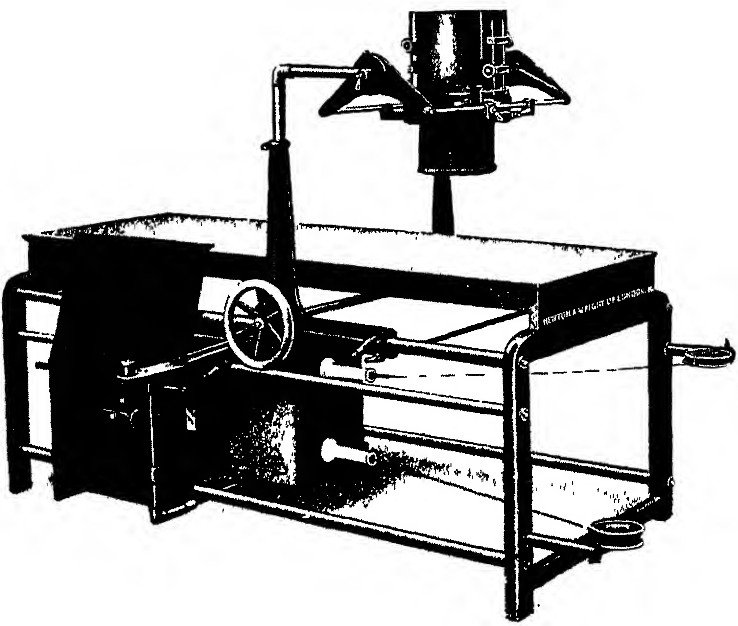


Fig. 111.—X-RAY TABLE WITH PROTECTIVE APRON AND ALTERNATIVE OVER-TABLE TUBE BOX.

the control handles as they project towards the operator. In Fig. 111 such an apron is shewn.

Largely on account of the difficulty in securing efficient protection from the upwardly directed rays, regular work for

prolonged periods with the tube under the table is looked upon with disfavour by many workers, and this question of over-exposure of the operator to X rays cannot be regarded too seriously (see page 155).

Alternative arrangements are sometimes fitted to a table, as in Fig. 111, so as to facilitate exposures with the *tube above the table.* This allows longitudinal movement of the tube along

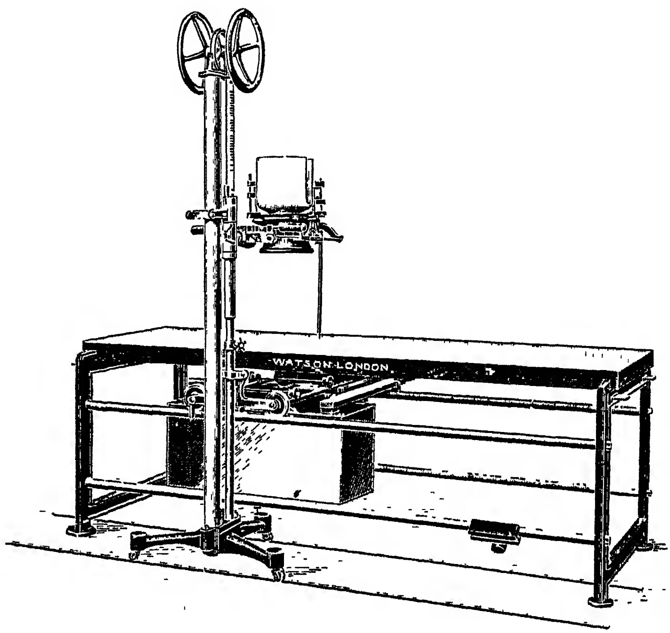


Fig. 112.—X-RAY TABLE USED IN COMBINATION WITH SEPARATE TUBE STAND.

with its supports, whilst cross movement is provided for on the horizontal bars carrying the tube box.

This is at times very useful, especially where compression may be desired, another arrangement for which is shewn later, on page 153. The alternative arrangement should be completely detachable, so as to leave an unobstructed table top; but, with that in view, the arrangement shewn in Fig. 112 will probably be preferred by anyone who possesses a serviceable tube stand of sufficient rigidity to allow moderate compression to be applied.

A piece of apparatus for *universal use* has often been aimed at in design; that is, a piece to serve as X-ray table, tube stand,

or vertical screening stand, as desired. All tables with arrangement for carrying a tube above the table can so serve in a more or less efficient way, and a rigid tube stand with any table with transradiant top can be made to serve all purposes in an emergency.

Where, however, space is limited, and work to be done is not large in amount but mixed in character, or where reduction of apparatus for the sake of portability has to be considered, a combined piece of apparatus designed to suit various purposes may prove very convenient.

Thus, during the late war such apparatus was very desirable for use in casualty clearing stations, where the bulk of the work was in screening fractures and localising foreign bodies, most conveniently done with tube under the table; but where occasional cases required the tube above the table for lateral views, or for screening of chest or abdomen in the vertical position. With such work in view alterations were made in the detailed design of an existing table, and several special additions made, with the resultant production of the combined table and tube stand shewn in Fig. 113. The various details of this table are described in the War Office Outfit Instructions, but most of them will readily be understood on inspection, and the annexed illustrations will serve to indicate the main points.

The *table top*, of three-ply wood, may be easily removed, leaving a frame on which a *stretcher* may be laid when it is undesirable to move the patient The table thus arranged is shewn in Fig. 113.

The *tube stand* is designed specially for use with the table, but may also be used as an independent stand by removing its **T**-shaped base from the rails on the table frame.

The *tube box*, cylindrical in shape, is made of composition lined with lead rubber, and is carried on a square metal stem, along the interior of which pass the control rods of a rectangular diaphragm, so that the opening may be regulated by the small hand wheels seen at the outer end of the stem. A third wheel there permits and controls rotation of the tube box about the axis of the stem.

A *screen* or *plate carrier* of aluminium is carried on a similar horizontal stem, and may be moved independent of the tube box in a vertical or horizontal direction, or may be moved in synchronism with the tube box in either or both directions by use

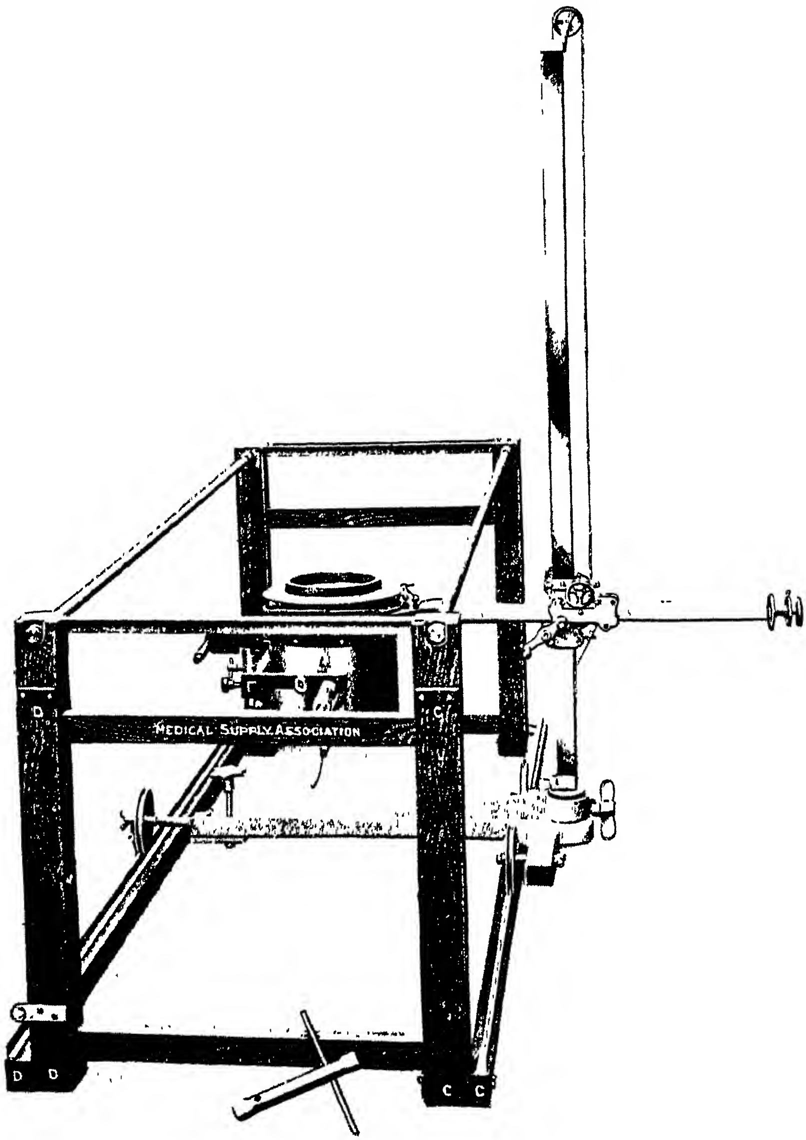


Fig. 113.—UNIVERSAL TABLE (A.M.D. PATTERN) WITH TOP AND SCREEN-CARRIER REMOVED.

of a gear case, which forms a side link between the two brackets carrying the tube box and screen carrier respectively, shewn in Fig. 158, on page 234. By rotating the upright pillar of the tube stand in its base socket, the tube box may be swung clear of the table and raised vertically. The tube box may then be rotated into a horizontal position, and be thus used to take

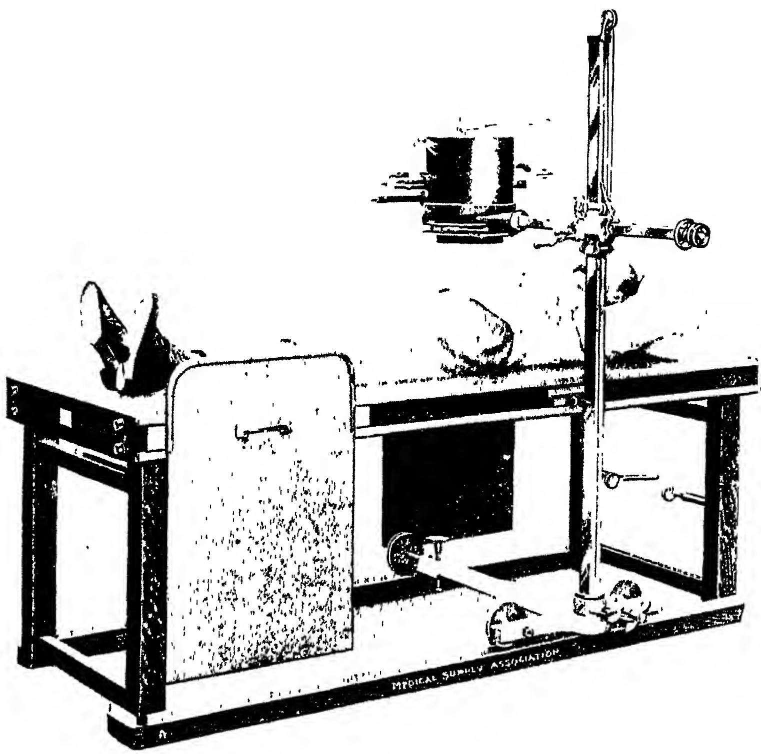


Fig. 114.—UNIVERSAL TABLE (A.M.D. PATTERN) ARRANGED TO TAKE VIEWS FROM ABOVE.

lateral views of a patient on the table, or it may be raised further vertically and rotated further till its opening faces downwards, so as to be used to take *views from above* the patient, as shewn in Fig. 114.

Protective aprons of lead rubber are supplied for use on either side of the table when working with the tube under the table.

Those should, of course, be moved opposite the tube box, and may be suspended on the side bars of the frame when the table top is removed for use with a stretcher.

For *vertical screening* two distance pieces, or links, of aluminium are employed to carry the screen carrier and its stem parallel to the tube box, whilst that is turned into a horizontal position with its opening facing one end of the table, the tube stand for the purpose being moved into its extreme position at that end. Fig. 115 shews the arrangement along with a vertical

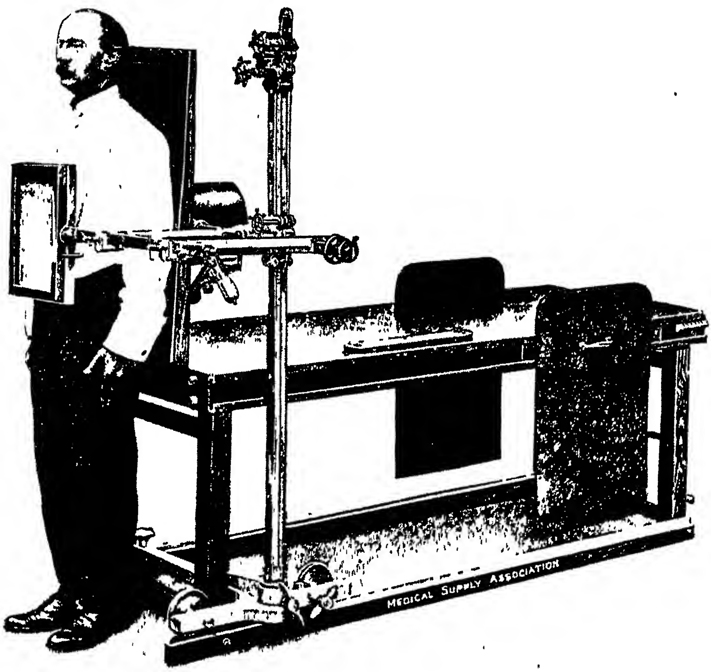


Fig. 115.—UNIVERSAL TABLE (A M.D. PATTERN) ARRANGED FOR VERTICAL SCREENING.

board supported in sockets on the table end for support of the patient.

For *stereoscopy* and *localisation* special fittings are provided to control shift of the tube and to make measurements; these will be noted later when the respective methods are described.

In a universal piece of apparatus like the above, when undertaking any one class of work many parts naturally seem superfluous, but they need not interfere with nor complicate the work in hand, and to any one who will take the small amount of trouble required to understand the various details, the table

described may, under appropriate circumstances, prove of very great value.

Certain *extra fittings* are more or less common to all tables, but those concerned with the tube box are of especial importance, and the principles of their use should be understood. This applies also to the tube boxes or stands.

Various special fittings or arrangements for stereoscopy and localisation will be more usefully described when those processes are discussed, but the various means of *centering the tube* for work from under the table may now be noticed. One method of doing this has already been described in connection with tube stands, on page 135, where the use of a sighting tube fitted in the side of a tube box is explained. The main object in securing the correct position of the tube relative to the tube box is to insure that the central ray of the cone of X rays passing through the diaphragm opening will be truly vertical in direction. This may be checked by various more direct means after the tube has been apparently centred in its box. (1) A tubular *anode finder*, shewn towards the front of Fig. 110, may be gripped by closing the diaphragm tightly upon its collar, and the resultant appearance on a fluorescent screen noted when rays are emitted from the tube. If the illuminated patch on the screen is circular the tube is correctly centred; if not circular, the tube should be moved until it is so. (2) Where a screen carrier is fitted to move in synchronism with the tube box, cross wires usually mark its centre, and the carrier should now be set so that the wires intersect exactly at the centre of the illuminated circle. Mechanical arrangements should make this latter setting unnecessary after the arrangement has been once tested and calibrated, and corresponding marking of suitable controls should make it possible thereafter to set the tube by the cross wires. Longitudinally the two parts—tube box and screen—must move together and, if they are not linked to move together across the table, their respective horizontal stems should carry scales clearly indicating their relative positions. This will be understood by reference to Fig. 158, where fittings are represented as designed especially for localisation of foreign bodies. (3) Without an anode finder the tube may be centred by *cross wire shadows.* In the absence of a rectangular diaphragm, a frame carrying cross wires may be arranged to fit centrally into, or over, the tube box opening.

With the tube in action, the shadow of these cross wires should correspond with those of the wires on the back of the screen, or the tube should be adjusted till they do so.

With a *rectangular diaphragm* each sector of the diaphragm in turn should be closed till only a small rectilinear opening remains, and the necessary adjustment of the tube should be made until the corresponding cross wire on the screen occupies the centre of the illuminated strip. With both sectors nearly closed, the small illuminated rectangular area will then coincide with the crossing of the wires and the tube will be truly centred.

Diaphragms are contrivances interposed in the cone of radiation emanating from an X-ray tube so as to cut off from a sensitive plate under exposure unnecessary rays, which would otherwise serve to confuse the record and blur the outline of the picture obtained.

In discussing X-ray tubes, it was pointed out that radiations are emitted from a small focal area of the antikathode. From that they proceed in straight lines, which collectively form a divergent cone, and thus the projected shadow of any object interposed across their path will be a magnified and distorted image of that object, according to its position relative to the tube and sensitive plane receiving the impression. This is discussed more fully in later sections when considering interpretation, localisation, and orthodiagraphy, and hardly requires demonstration; but the point will be made clear by reference to the annexed figure (Fig. 116).

There M N is supposed to be a sensitive plane—fluorescent screen or sensitive plate—receiving the rays emanating from an X-ray tube below. The rays pass through equidistant points on the plane A K, which, however, lies at an angle to the plane M N, this being the more common condition of objects exposed in practical radiography. The magnification of A K at M N is readily evident, and the distortion is represented by the inequality of the distances between the projected points A^1, B^1, C^1, etc. On the larger scale of actual working conditions this effect is proportionately more marked, though the inclination of A K is here made somewhat extreme for the purpose of clearness.

The distortion is greater in the parts exposed to the more divergent rays, and is relatively neglible only for a small area on each side of the central ray (X Y). Thus, in a radiogram of a large area, while the central parts will be represented with

some degree of accuracy in proportion and relation, the image of the marginal parts will be so magnified and distorted as to be of little or no real value.

Further, from the walls of the X-ray tube, and from other metal parts than the target, emanate irregular rays, sometimes called "secondary" X rays. These are due to failure to confine the origin of kathode rays strictly to the kathode, or to bring to a focus all the rays formed there, as at its edges. Those irregular kathode rays, on their impingement on the

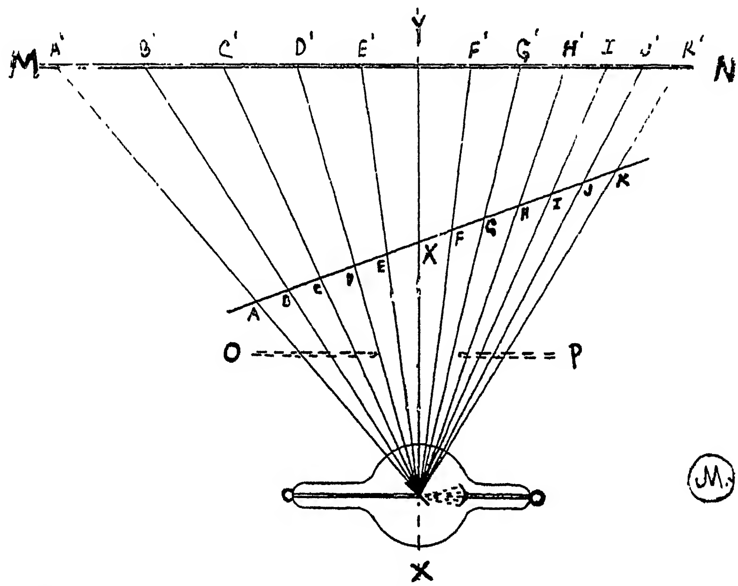


Fig. 116.—DIAGRAM OF DIVERGENT RADIATION FROM X-RAY TUBE.

walls of the tube or other parts in their path, give rise to X rays, which from their irregular origin and distribution serve to confuse the projection of the regular radiation.

These secondary X rays are doubtless responsible for much of the general fogginess of negatives, and for the lack of sharpness in outline and of definition in detail so frequently noted on screen or radiogram.

If a diaphragm opaque to the radiation (usually of lead or zinc) be interposed between the tube and the object exposed, as at O P in Fig. 116, the marginal distortion referred to will be to some extent obviated by limiting the view to more central parts, and definition of outline and detail will be improved by cutting off much of the secondary radiation described above.

An adjustable flat diaphragm is for this purpose attached to each tube box or shield, so as to intercept the sheaf of X rays passing from the tube. This diaphragm may be of iris pattern, similar to those employed in most ordinary photographic cameras, and on the boxes of tube stands is commonly of this form.

In Fig. 104 may be seen the projecting handle by means of which the circular aperture may be adjusted concentrically to any desired size. When situated below the patient, this can be so adjusted while the effect is noted on a fluorescent screen above, as discussed on page 137. In that situation, however,

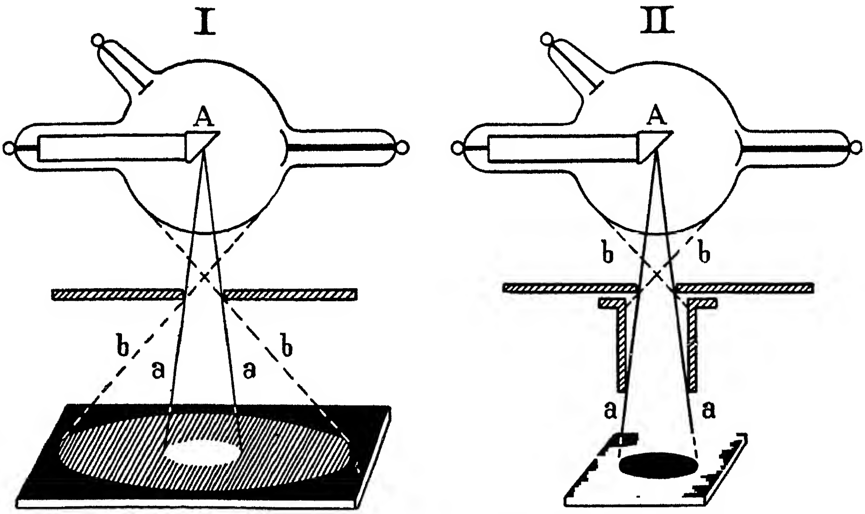


Fig. 117.—Diagram of Flat and Cylinder Diaphragms.

a diaphragm with rectangular aperture is preferred, since it permits adjustment in two directions independently and also permits the use of heavier metal with consequently greater protection.

Such flat diaphragms cannot cut off all the secondary rays, and another design, of cylindrical form, is frequently employed to cut them off more effectually.

In Fig. 117 are reproduced two diagrams, representing the advantage of those "cylinder diaphragms" over the flat or disc form.

The cylinders are not adjustable and therefore less convenient in use, but the results obtained are slightly superior. Used with compressors, as discussed in the succeeding section, those cylinders act also as distance pieces on the front of the

tube box (see Fig., 122) and a diameter may be chosen suitable to the part under exposure.

In addition to the secondary radiation from the apparatus, as above considered, there is further trouble from secondary radiation in the patient's body.

This *scattered radiation* is produced by the passage of X rays through the body, as well known physically to occur when X rays pass through matter, and the effect is likened to the blurring effect on a light seen through fog.

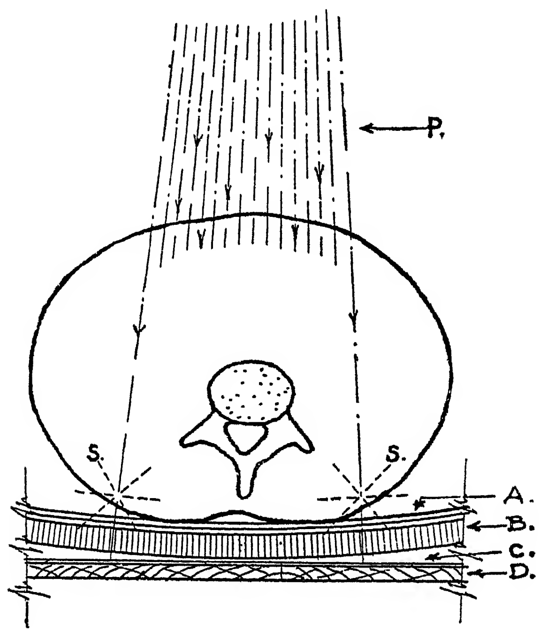


Fig. 118.—Diagram of Radiation from X-ray Tube and Scattered Radiation with Grid Diaphragm.

The radiation thus produced and arising so near the plate has a decided effect in blurring the outline, and obscuring the definition, of radiograms taken through the thicker parts of the body.

Fig. 118 shews the two types of radiation with their sources, the desired X-radiation P from the tube and the secondary or scattered radiation S from the patient's tissues. With the latter left uncontrolled it can readily be seen how its incidence will produce a general fogging of the exposed plate.

The *Potter-Bucky Diaphragm* is an ingenious contrivance to eliminate the effect of those scattered rays, and this it un-

doubtedly does to a very considerable extent. This is interposed between the patient and the sensitive plate, as shewn at B in Fig. 118, and consists of a grid formed of opaque strips with transradiant intervals.

As shewn in Fig. 118, such an arrangement will effectively check all but a small percentage of the divergent secondary rays, whilst permitting passage of the primary rays, to which the width of the strips is made parallel. The grid is curved so as to form a segment of a circle of 25 in. radius, and the X-ray tube must be set at this distance of 25 in., so that its focal spot will coincide with the centre of curvature of the diaphragm. Fig. 119 shews this curvature, but the grid is there covered by an aluminium support for the patient. Fig. 120 partially shews the grid and its mechanism, as also the plate carrier under the grid.

Originally a stationary grid was employed, and improvement was noted in the resultant radiograms, but the pattern of the grid superimposed upon each more than counterbalanced the benefit. Movement of the grid is therefore arranged at right angles to the length of the strips, and exposure is made whilst this movement is at a uniform rate, so that each part of the exposed plate has a similar amount of radiation allowed to pass to it through the transradiant strips as they move across its surface. This movement is produced by a spring mechanism, and controlled by a plunger moving against air pressure, or in oil. By regulation of this pressure the speed of movement can be regulated so as to allow for the necessary time of exposure whilst the grid is at the middle section of its traverse.

In earlier models some difficulty was experienced, on account of the longer exposure made necessary by the absorption of a percentage of the primary rays by the lead strips. This difficulty was, however, overcome, and with a later model in which the lead strips are 0·5 mm. thick and 1 mm. apart, and working with films and double accelerating screens, any part can be radiographed with a single operation of the grid.

Exposure time should be from two to three times that proper for ordinary conditions, and best results are said to be obtained with an equivalent air-gap between points of $3\frac{1}{2}$ to $4\frac{1}{2}$ in. for a gas tube, or 5 in. for a Coolidge.

A secondary advantage of this diaphragm is that the marginal rays from the tube need not be cut off by a tube box diaphragm, and a wide area—such as two hips—may be included in one plate.

For radiograms of the trunk region this device has proved most valuable. The detail of thoracic and lumbar vertebræ so obtained is striking, as may be seen from Fig. 199, on page 278;

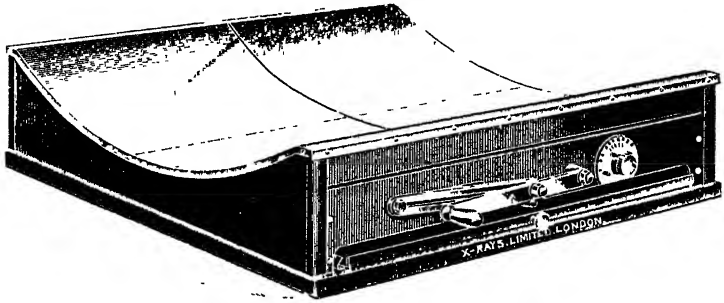


Fig. 119.—POTTER-BUCKY DIAPHRAGM.

whilst for kidney and gall bladder diagnosis a grid diaphragm is considered by many as an essential. The cost of the contrivance has so far rendered its use somewhat limited, but where the volume or importance of the work done may justify

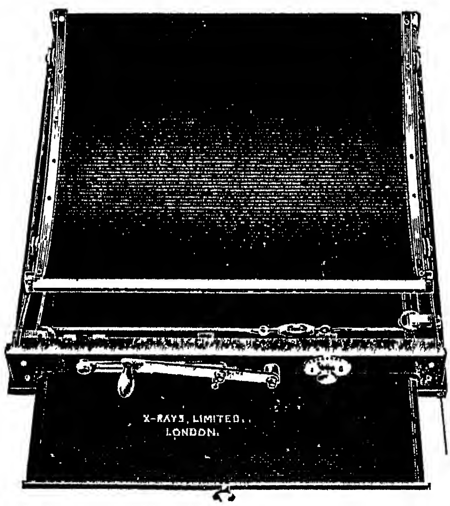


Fig. 120.—POTTER-BUCKY DIAPHRAGM, COVER REMOVED.

the expenditure, the resultant radiograms will be found undoubtedly improved in quality.

Compressors.—In order to inhibit movement, and to secure closer apposition of the plate to the part to be radiographed, especially when such part is deeply situated, most workers employ some form of compression.

In abdominal work principally is this employed, as in determining presence of calculus in a kidney. Compression may be exercised by simple means, or by one of the more elaborate compressors listed by instrument makers. Even for special regions simple arrangements will be found thoroughly serviceable and efficient, but here, as elsewhere, each worker, after appreciating the principles of their use, must exercise his choice according to taste and purse, always remembering that

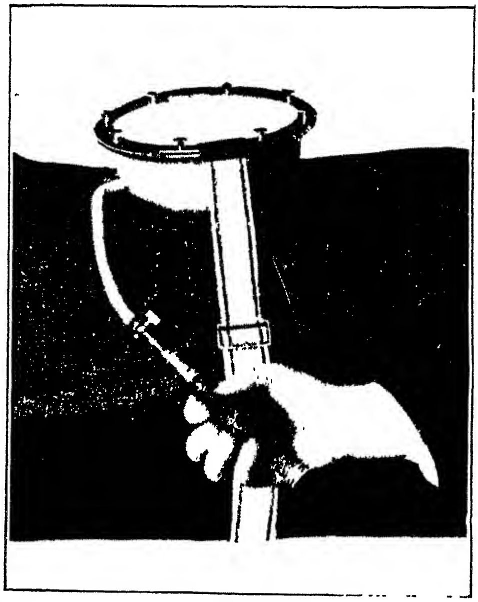


Fig. 121.—ABDOMINAL COMPRESSOR—PNEUMATIC.

the quality of the work produced depends much more upon other factors, chiefly himself.

As applied for radiography of the kidneys all compressors exert pressure on the abdomen, whereby diaphragmatic respiration is restricted and the concomitant movement of the kidneys minimised.

In the simplest form a *strap* or *binder* is passed from one side of the table to the other, so as to cross over the abdomen of the patient whilst he lies on his back. The strap may be tightened by ratchet or other arrangement at one side of the table, and, in addition, a Japanese paper air cushion may be placed between it and the patient's abdomen. A similar arrangement is seen in Fig. 121, where a rubber bag is employed.

Rubber has the disadvantage of being slightly opaque to X rays, but this may be discounted. The arrangement shewn constitutes a very serviceable compressor for inclusion in a portable outfit. An inflated bag may, however, distribute the pressure too widely, and a better arrangement is that of a

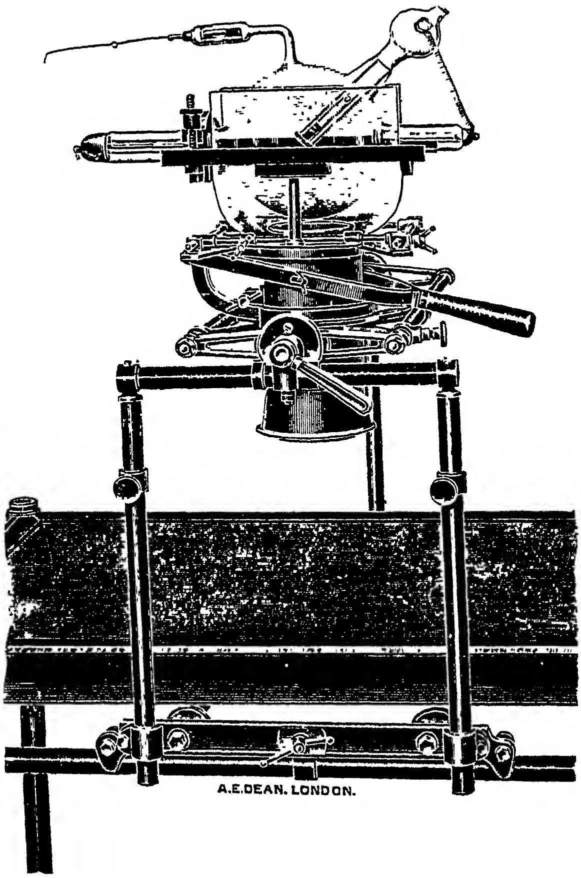


Fig. 122.—Mechanical Compressor to-be attached to Table.

series of small soft cushions of increasing diameter placed concentrically over the area to be exposed. The smallest cushion is placed next the patient, thus forming the apex of a blunt cone composed of the successively larger cushions; and pressure applied on this will displace the mobile viscera outwards from the centre of the area.

These cushions must be made of selected material, such as

pure lamb's wool, since ordinary flock and other materials are decidedly opaque to X rays.

Compression may be exercised by any tube box fitted with a *cylindrical diaphragm*, such as shewn on the tube stands in Figs. 105 or 112, or above the table in Fig. 111, provided that the fittings are rigid enough, but one of the more elaborate permanent arrangements, such as that shewn in Fig. 122, will be found convenient by workers where much kidney investigation is undertaken (also shewn on table in Fig. 179, on page 262).

Under any of those mechanical compressors the wedge series of cushions described above should be inserted.

With a cylinder diaphragm the tube must be carefully set before the compressor is put in position. When set in position, even if the tube be properly adjusted and the end of the cylinder be set on the front of the body correctly, a slight wrong inclination of the apparatus may direct the rays so as to illuminate the wrong area of the region undergoing exposure. As already explained, such an unfortunate contingency is obviated by previous screening with the tube set below the patient; hence, unless the tube can be left in position for a series of exposures, the latter position of the tube may be considered preferable for inexperienced workers.

A worker gradually eliminates those possibilities of error as he gains experience, but he must take pains all the more whilst lacking that advantage.

For compression of the abdomen an inflated rubber bag may be employed, placed under the patient whilst he lies face downwards on a table with transradiant top and with the X-ray tube set below.

The weight of the patient here acts as a compressing force to inhibit, as far as possible, abdominal movements; and that force may be augmented by placing weight on a rigid board placed above the sensitive plate as it lies over the lumbar region.

Instead of the rubber bag, the wedge series of cushions already described may be employed, but it is more customary to exercise compression on the abdomen of the patient as he lies face upwards on the table.

In favour of the latter position it should be noted that thoracic movements are free, whereas with face downwards respiratory movements impart to the whole body more or less movement up and down, and the plate on the back moves

correspondingly, thus tending to produce a certain amount of blurring of outline in the resultant radiogram. This largely accounts for the preference for the other position by workers as they gain experience sufficient to discount the difficulties of the exposure. The details of setting for radiography of the kidneys are explained later, in the chapter on diagnosis (p. 505).

For other parts special means of compression are seldom employed.

With a modern outfit, and using the most rapid plates or films with intensifying screens, no exposure is required of the soft parts longer than a few seconds, so that the patient himself may readily inhibit all movement by holding his breath for that brief period.

With an outfit of low power necessitating comparatively long exposures, however, every means must be employed to secure steadiness of the part and to inhibit movements, both physiological and accidental.

Protective Devices.

In preceding sections, whilst describing apparatus, reference has been made at various points to the necessity for provision of protection of operator and patient from injurious exposure to X rays. The danger to the patient from over-exposure at a single operation has been obvious since the early days of radio-therapy, and due precautions are usually taken to control and distribute the dosage so as to obviate over-exposure of the skin of any part; but the cumulative danger to the operator of repeated minimal exposures has not hitherto been sufficiently realised nor provided against. Modern attempts in radiotherapy to attain maximum exposure of deeper parts render protection of the skin from over-exposure a fundamental consideration.

Protection of the operator is not less important, but the necessity is less obvious, and must therefore be impressed upon all X-ray workers.

The principal danger of exposure occurs in screen work, and during such work an operator should always have at least his hands protected. Gloves of thick rubber impregnated with lead should be worn for handling the screen, and a hint worth remembering when consulted about a patient by a practitioner eager and anxious to "see for himself," is to allow the practitioner to hold the screen in position during what will probably be an unduly prolonged illumination.

The danger to the patient of such prolonged screen examinations must be borne in mind, as also the danger involved in taking a series of radiograms of the same part, especially if the tube be soft.

Protection of other parts of the operator is also necessary, since, although it is difficult to substantiate reports of X-ray workers having been found sterile owing to unconscious exposure of the testicles to radiation, experiments on animals demonstrate that X rays have definite arrestive action on the special functions of the generative organs.

The conditions and degree of this effect still await investigation, but absolute protection from X rays should be the criterion aimed at by every worker.

In occasional work, or working under conditions such as are necessarily met with in war service, this ideal may not be attainable in each installation, and the worker should therefore take all the more precaution in his procedure.

The following summary of precautions appears in the War Office Instructions for use of Field Service X-ray Outfits:—

PRECAUTIONS TO BE OBSERVED BY X-RAY OPERATORS.

1. It is of the greatest importance that all those engaged in X-ray work should realise the dangers to which they are subject, and the precautions necessary to obviate them.

2. Many cases of malignant disease caused by X rays have been recorded, and it has been established that the superficial lesions which mark the onset of malignant disease when induced in this manner are generally caused by X rays of a "soft" type; hence special precautions should be taken against undue exposure to "soft" X rays, and operators are cautioned on no account to expose themselves to the direct unscreened rays coming from the X-ray tube.

3. Exposure of the operator to X rays of a "harder" character, *i.e.*, of a more penetrating type, should, however, be guarded against in a no less determined manner, for the generative organs in man are especially vulnerable to X rays, and permanent sterility may occur as a sequel to over-exposure to them. Exposure of other parts of the body to "hard" X rays is also known to result in what are called "delayed X-ray burns," which often make their appearance at prolonged intervals after the initial damage has been done.

4. Generally speaking, the lesions caused by X rays do not appear suddenly, but are insidious in onset, with the result that the damage is often done long before it is apparent.

5. It should be remembered that during X-ray screen examinations, when the operator remains very near to the X-ray tube, he is receiving fractional doses of the rays.

6. *Protective gloves and aprons* should *always* be worn both by the operator and assistants while the tube is in action, as it is impossible to

afford complete protection by the tube boxes. Ordinary gloves, cotton or leather, should be worn underneath unlined protective gloves to absorb secondary radiation.

7. It must be emphasised that, as far as possible, *direct screen examination* should be reduced to a minimum, although the lead glass now used affords considerable protection. This method should mainly be used where it is difficult or impossible to obtain the required result by other means. Furthermore, screen examination alone can never be relied on for a diagnosis of the absence of small pieces of metal or fracture, and a permanent record of each case should always be made.

8. When screening is being done, it is advisable to work with as small an aperture of the diaphragm as possible, and the operator should stand to one side unless during the period of actual observation.

9. The operator should, whenever possible, stand at a considerable distance from an X-ray tube in action; and at all times he should stand towards the antikathode end of the tube.

In supplying outfits for army service, efforts were made towards standardisation, and it was, above all, found necessary to test the protective material supplied from various sources. Towards this end valuable research work was carried out, and routine methods of inspection instituted, at the War Office X-ray Laboratory. Most installations existing in hospitals taken over for army purposes were found defective in protective arrangements, some dangerously so, and this experience has been confirmed in the inspection of permanent installations carried out on behalf of the recently formed X-ray and Radium Protection Committee.

The salient points are well summarised in the preliminary report (July, 1921) of that Committee, and the recommendations should be carefully noted by all responsible in any degree or respect for X-ray installations. The report is here copied, along with a subsequent memorandum regarding arrangements made with the National Physical Laboratory for the testing of all protective materials and devices.

X-RAY AND RADIUM PROTECTION COMMITTEE.

PRELIMINARY REPORT.

Introduction.

The danger of over-exposure to X rays and radium can be avoided by the provision of efficient protection and suitable working conditions.

The known effects on the operator to be guarded against are :—

(1) Visible injuries to the superficial tissues which may result in permanent damage.

(2) Derangements of internal organs and changes in the blood. These are especially important, as their early manifestation is often unrecognised.

General Recommendations.

It is the duty of those in charge of X-ray and Radium Departments to ensure efficient protection and suitable working conditions for the *personnel*.

The following precautions are recommended:—

(1) Not more than seven working hours a day.

(2) Sundays and two half-days off duty each week, to be spent as much as possible out of doors.

(3) An annual holiday of one month or two separate fortnights.

Sisters and nurses, employed as whole-time workers in X-ray and Radium Departments, should not be called upon for any other hospital service.

Protective Measures.

It cannot be insisted upon too strongly that a primary precaution in all X-ray work is to surround the X-ray bulb itself, as completely as possible, with adequate protective material, except for an aperture as small as possible for the work in hand.

The protective measures recommended are dealt with under the following sections:—

i. X rays for diagnostic purposes.
ii. X rays for superficial therapy.
iii. X rays for deep therapy.
iv. X rays for industrial and research purposes.
v. Electrical precautions in X-ray Departments.
vi. Ventilation of X-ray Departments.
vii. Radium therapy.

It must be clearly understood that the protective measures recommended for these various purposes are not necessarily interchangeable; for instance, to use for deep therapy the measures intended for superficial therapy would probably subject the worker to serious injury.

I. X Rays for Diagnostic Purposes.

(1) *Screen examinations.*

(*a*) The X-ray bulb to be enclosed as completely as possible with protective material equivalent to not less than 2 mm. of lead. The material of the diaphragm to be equivalent to not less than 2 mm. of lead.

(*b*) The fluorescent screen to be fitted with lead glass equivalent to not less than 1 mm. of lead and to be large enough to cover the area irradiated when the diaphragm is opened to its widest. (Practical difficulties militate at present against the recommendation of a greater degree of protection).

(*c*) A travelling protective screen, of material equivalent to not less than 2 mm. of lead, should be employed between the operator and the X-ray box.

(*d*) Protective gloves to be of lead rubber (or the like) equivalent to not less than ½ mm. of lead and to be lined with leather or other suitable material. (As practical difficulties militate at present against the recommendation of a greater degree of protection, all manipulations during screen examination should be reduced to a minimum.)

(*e*) The X-ray bulb to be used at as great a distance and emitting as little radiation as are consistent with the efficiency of the work in hand. Screen work to be as expeditious as possible.

(2) *Radiographic Examinations ("overhead") equipment.*

(*a*) The X-ray bulb to be enclosed as completely as possible with protective material equivalent to not less than 2 mm. of lead.

(*b*) The operator to stand behind a protective screen of material equivalent to not less than 2 mm. of lead.

II. X Rays for Superficial Therapy.

It is difficult to define the line of demarcation between superficial and deep therapy.

For this reason it is recommended that, in the re-organisation of existing, or the equipment of new, X-ray Departments, small cubicles should not be adopted, but that the precautionary measures suggested for deep therapy should be followed.

The definition of superficial therapy is considered to cover sets of apparatus giving a maximum of 100,000 volts (15 cm. of spark-gap between points; 5 cm. spark-gap between spheres of diameter 5 cm.).

Cubicle System.—Where the cubicle system is already in existence it is recommended that:—

(1) The cubicle should be well lighted and ventilated, preferably provided with an exhaust electric fan in an outside wall or ventilation shaft. The controls of the X-ray apparatus to be outside the cubicle.

(2) The walls of the cubicle to be of material equivalent to not less than 2 mm. of lead. Windows to be of lead glass of equivalent thickness.

(3) The X-ray bulb to be enclosed as completely as possible with protective material equivalent to not less than 2 mm. of lead.

III. X Rays for Deep Therapy.

This section refers to sets of apparatus giving voltages above 100,000.

(1) Small cubicles are not recommended.

(2) A large, lofty, well-ventilated and lighted room to be provided.

(3) The X-ray bulb to be enclosed as completely as possible with protective material equivalent to not less than 3 mm. of lead.

(4) A separate enclosure to be provided for the operator, situated as far as possible from the X-ray bulb. All controls to be within this enclosure, the walls and windows of which to be of material equivalent to not less than 3 mm. of lead.

IV. X Rays for Industrial and Research Purposes.

The preceding recommendations for voltages above and below 100,000 will probably apply to the majority of conditions under which X rays are used for industrial and research purposes.

V. Electrical Precautions in X-ray Departments.

The following recommendations are made:—

(1) Wooden, cork, or rubber floors should be provided; existing concrete floors should be covered with one of the above materials.

(2) Stout metal tubes or rods should, wherever possible, be used instead of wires for conductors. Thickly insulated wire is preferable to bare wire. Slack or looped wires are to be avoided.

(3) All metal parts of the apparatus and room to be efficiently earthed.

(4) All main and supply switches should be very distinctly indicated. Wherever possible double-pole switches should be used in preference to single-pole. Fuses no heavier than necessary for the purpose in hand should be used. Unemployed leads to the high-tension generator should not be permitted.

VI. Ventilation of X-ray Departments.

(1) It is strongly recommended that the X-ray Department should not be below the ground level.

(2) The importance of adequate ventilation in both operating and dark rooms is supreme. Artificial ventilation is recommended in most cases. With very high potentials coronal discharges are difficult to avoid, and these produce ozone and nitrous fumes, both of which are prejudicial to the operator. Dark rooms should be capable of being readily opened up to sunshine and fresh air when not in use. The walls and ceilings of dark rooms are best painted some more cheerful hue than black.

VII. Radium Therapy.

The following protective measures are recommended for the handling of quantities of radium up to one gram:—

(1) In order to avoid injury to the fingers the radium, whether in the form of applicators of radium salt or in the form of emanation tubes, should be always manipulated with forceps or similar instruments, and it should be carried from place to place in long-handled boxes lined on all sides with 1 cm. of lead.

(2) In order to avoid the penetrating rays of radium, all manipulations should be carried out as rapidly as possible, and the operator should not remain in the vicinity of radium for longer than is necessary.

The radium when not in use should be stored in an enclosure, the wall thickness of which should be equivalent to not less than 8 cm. of lead.

(3) In the handling of emanation all manipulations should, as far as possible, be carried out during its relatively inactive state. In manipulations where emanation is likely to come into contact direct with the fingers thin rubber gloves should be worn. The escape of emanation should be very carefully guarded against, and the room in which it is prepared should be provided with an exhaust electric fan.

Existing Facilities for ensuring Safety of Operators.

The Governing Bodies of many Institutions where radiological work is carried on may wish to have further guarantees of the general safety of the conditions under which their *personnel* work.

(1) Although the Committee believe that an adequate degree of safety would result if the recommendations now put forward were acted upon, they would point out that this is entirely dependent upon the loyal co-operation of the *personnel* in following the precautionary measures outlined for their benefit.

(2) The Committee would also point out that the National Physical Laboratory, Teddington, is prepared to carry out exact measurements upon X-ray protective materials, and to arrange for

periodic inspection of existing installations on the lines of the present recommendations.

(3) Further, in view of the varying susceptibilities of workers to radiation, the Committee recommend that wherever possible periodic tests, *e.g.*, every three months, be made upon the blood of the *personnel*, so that any changes which occur may be recognised at an early stage. In the present state of our knowledge it is difficult to decide when small variations from the normal blood-count become significant.

MEMORANDUM NO. 2.

In view of the widespread uncertainty and anxiety as to the efficacy of the various devices and materials employed for the purposes of protection against X rays, the X-ray and Radium Protection Committee strongly advises that the heads of X-ray Departments of Hospitals and other institutions should safeguard themselves and their staff on this score by recommending to the Hospital Authorities the adoption of the following precautions :—

(1) The various protective appliances should be inspected and reported on by the National Physical Laboratory (N.P.L.), Teddington. In the event of an adverse report, early steps should be taken to carry out the recommendations of the Laboratory. The Laboratory is prepared, wherever possible or expedient, to date and engrave (or otherwise suitably mark) the N.P.L. monogram on such appliances as provide the full measure of protection laid down in the Preliminary Report (July, 1921) of the Protection Committee. It should be pointed out that, in the case of materials which may deteriorate, *e.g.*, lead rubber, such inspection should be periodic, say, every twelve months.

(2) Within the Committee's recent experience, the working conditions of X-ray Departments, *e.g.*, lay-out of installations, degree of scattered radiation, ventilation, high-tension insulation, etc., are often unsatisfactory. It is recommended that such conditions be inspected by the N.P.L., and that early steps be taken to give effect to such alterations as may arise out of the report. It is advised that, in the planning of new radiological departments, advantage be taken of the facilities available at the N.P.L.

(3) Manufacturers of X-ray apparatus are also invited to assist in reassuring the public by actively co-operating with the Committee in its recommendations. It is suggested that protective materials or equipment should not be sold or incorporated into an installation unless accompanied by a specification based upon an N.P.L. certificate or report, stating in terms of lead, the degree of protection afforded.

In the interests of both the trade and profession, it is urged that manufacturers should put themselves into a position to be able to guarantee that their apparatus complies completely with the recommendations of the Committee.

(4) The Committee recommends that the various measuring instruments, dealing with the measurement of current (ammeters and milliammeters) and voltage, be standardised by the N.P.L. With reference to the measurement of secondary voltage, the Committee recommends that every installation should be provided with adequate

means for enabling this to be easily effected, *e.g.*, by kilovoltmeter, sphere-gap voltmeter, or the like.

(5) The Committee would further urge that Heads of X-ray Departments should insist upon complete N.P.L. inspection of imported materials and apparatus.

In arranging new installations the paramount importance of

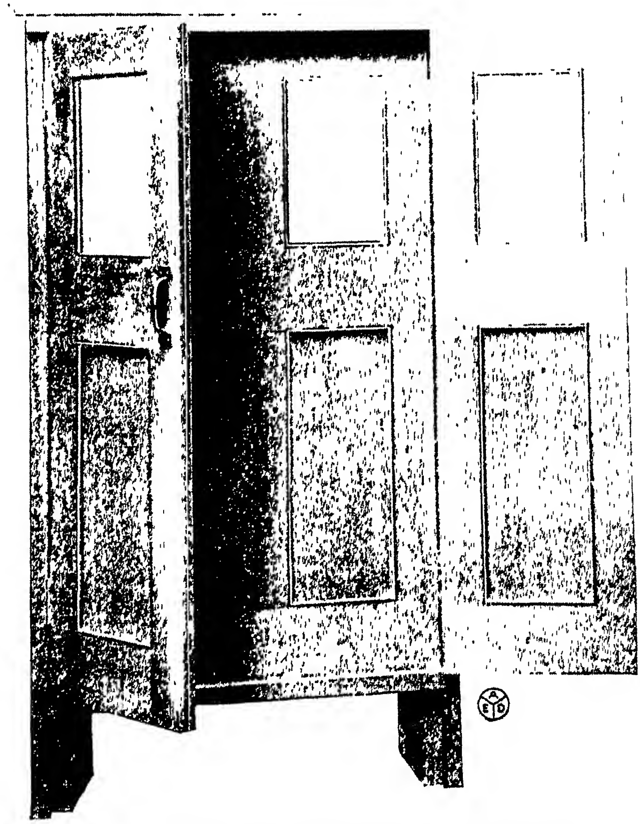


Fig. 123.—PROTECTIVE SCREEN FOR X-RAY OPERATOR.

protection should always be borne in mind, and each piece of apparatus should be considered in relation to this.

A *protective cabin*, as referred to in Section III of the above report, from which the operator may control the apparatus whilst he is entirely shut off from all X-radiation, may be employed, the switchboard, break, etc., being mounted inside. Such a cabin is usually constructed of wood lined with thick sheet lead, and is provided with lead glass windows, through which the apparatus may be observed.

As an alternative, the patient and apparatus may be enclosed in a similar ray-proof structure, whilst the operator is free to move about outside, but with a nervous patient such an arrangement would be inconvenient and somewhat risky for the patient.

A *protective screen*, lined with lead, behind which the operator may retire during a prolonged exposure, or behind which may be arranged his control switchboard, is often employed in place of a fitted cabinet. Such screens are more or less portable, as shewn in Fig. 123, and may be arranged as required.

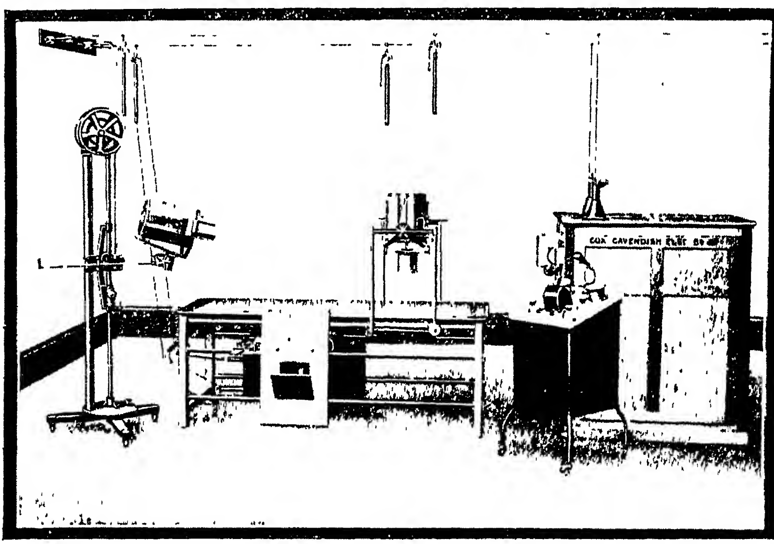


Fig. 124.—ARRANGEMENT OF APPARATUS WITH OVERHEAD LEADS.

For the purpose of rendering partition walls non-trans-radiant, a mixture of commercial barium sulphate with cement has recently been used in Manchester. Five parts of barium with one of plaster forms a convenient mixture, and a layer, $1\frac{1}{2}$ inches thick, of this material gives most effective protection.

The comparative cheapness of barium sulphate and the ease of application of such a plaster render this method most valuable.

High-tension fittings are referred to in Sections V and VI of the report quoted on page 159, and it is essential for efficient working and for the health of the operators that the points there summarised should receive most careful attention.

An X-ray room must be of *dimensions* sufficient to allow adequate ventilation as well as to provide for convenient arrangement of apparatus. A suitable size for ordinary purposes is about 25 feet square (or equivalent) of floor space and 12 feet high. The older practice of cramming X-ray apparatus into small ill-ventilated apartments cannot be too strongly condemned, either from the point of view of quality of work done or of the health of the operators. The particular arrangement of the separate pieces of apparatus will naturally depend somewhat upon the actual shape of the room, and also upon the nature of the work to be mainly undertaken.

For ordinary work without a screening stand, a simple arrangement is suggested in Fig. 124. This shews overhead

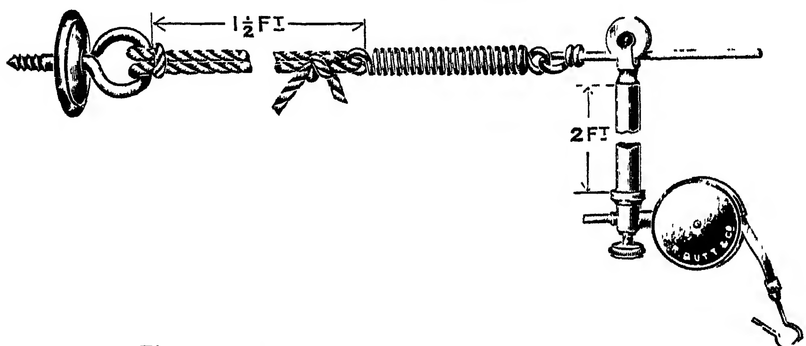


Fig. 125.—FASTENING FOR OVERHEAD H.T. LEADS.

high-tension leads stretched between two opposite walls of the room, from which leads connection is made to the X-ray tube, wherever that may be desired for use.

Fig. 125 shews one arrangement of detail in fastening those overhead leads, which must be insulated from the walls; this detail naturally varies with the ideas of the engineer responsible for the fitting of the X-ray room. It should, however, be stipulated in all cases that the horizontal leads be of sufficient diameter to minimise the brush discharge so commonly present with exposed high-tension leads. The effect of this discharge on the atmosphere of the room is very undesirable, whilst it is, at the best, difficult to arrange adequate ventilation of a darkened room during prolonged periods of use.

With this in view, *stout metal tubes* or *rods* (preferably of aluminium) are recommended, and those may be supported by simple insulating hangers from the ceiling in any position,

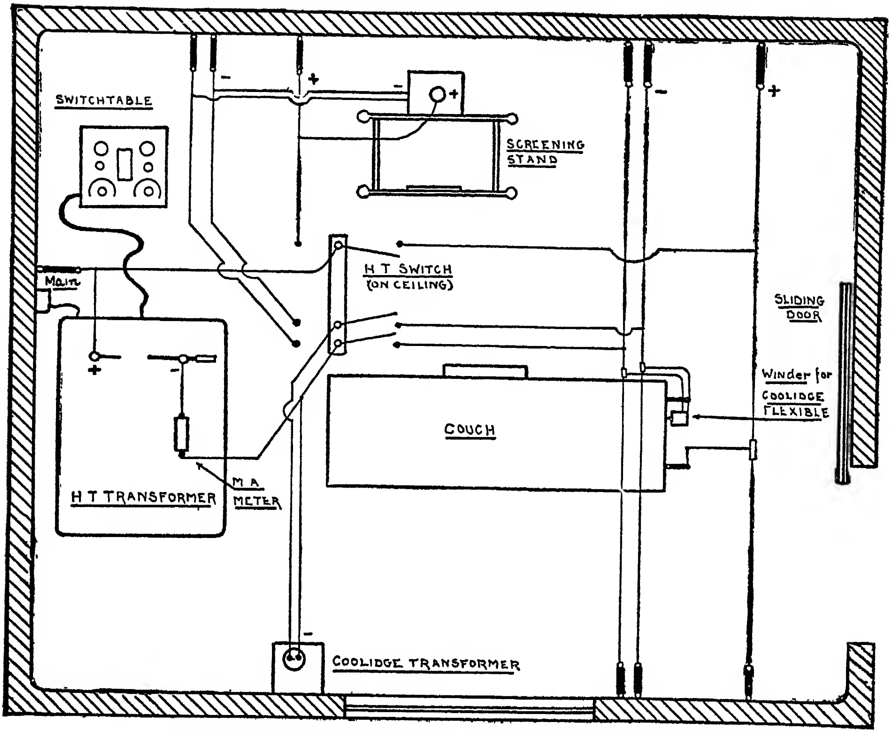


Fig. 126.—ARRANGEMENT OF APPARATUS WITH CHANGE-OVER H.T. SWITCH.

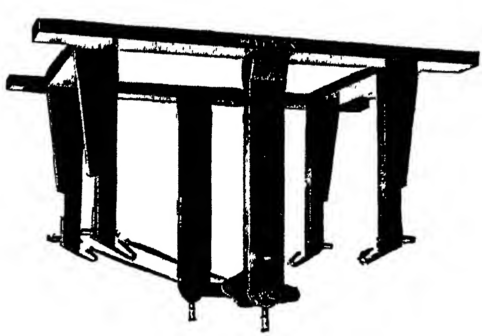


Fig. 127.—HIGH-TENSION CHANGE-OVER SWITCH.

since their rigidity obviates the danger of sagging, to prevent which the more flexible wire leads have to be strained tightly, as shewn in Figs. 125 and 126. The connections from those overhead leads to the X-ray tube should be as short as possible, and no loose ends nor slack loops must be permitted.

For convenience of working, spring rheophores (like spring tapes), as shewn in Fig. 125, are found very serviceable and insulating handles, as in Fig. 124, are commonly fitted for adjustment of position.

Fig. 126 shews a plan of connections for a more elaborate installation. This provides for the use, if desired, of a Coolidge tube, and includes a separate screening stand in addition to the usual couch or table. For alternative use of those two pieces of apparatus a *change-over switch* is included in the high-tension circuit, so that the operator may use one in succession to the other without the inconvenience of disconnecting and making fresh connections each time.

Fig. 127 shews one of the various types of switch so employed. Such a switch is, however, not intended to be used whilst current is passing in the high-tension circuit.

Other details in the fitting of the apparatus in the X-ray room are for the consideration of the engineer responsible for the installation, and must naturally be adapted to suit existing circumstances and potential requirements of the particular installation concerned.

CHAPTER V

PHOTOGRAPHY

For success in radiography, it is essential that the operator should have an intimate knowledge of the installation with which he is working, and he must ascertain for himself the conditions of its highest efficiency.

The various factors involved have been discussed in preceding chapters, and the questions of supply, generation of high-tension current, and production of X rays being thus understood, some points requiring attention in the actual production of a radiogram are now noted.

The most careful attention must be paid to every detail of the process; no point, however minor, is unworthy of attention if the best results be desired.

1. Choice of Tube.

It has already been explained how tubes vary in hardness and in consequent power of penetration.

It was noted that a tube should always be chosen with due regard to the nature of the work to be done, and that for photographic work a tube should be selected of a hardness in direct relation to the density of the part to be exposed.

Where bone is concerned, this factor will be found to correspond roughly to the actual thickness of the part, but it is otherwise in the case of radiograms made of the kidney, bladder and other hollow, or soft, parts, in which the presence of calculus is the usual point to be settled.

In each of these cases, if a tube were used corresponding in hardness to the thickness of the part, the rays would probably penetrate the calculus, and leave no discernible trace of its existence on the sensitive plate.

The following table indicates the quality of tube found suitable for radiographing different parts. Added to it is a table of exposure times, which will be referred to in the

following section. The majority of experienced workers prefer to use tubes relatively somewhat soft. A minority hold that harder tubes allow reduction in exposure time, and that though the resultant negatives are very thin in quality, and therefore unsatisfactory for direct examination, from them excellent bromide prints may be made.

EXPOSURE TIMES.

(*See explanatory notes.*)

ANTIKATHODE OF TUBE SET AT 10 INCHES FROM NEAREST SURFACE OF PART.

	Parts in Order of Density	M.A. Seconds.
A *soft tube*, Benoist No. 5, should be used for—	Fingers.	12
	Toes.	12
	Forearm.	25
	Calculus in kidney.	200
	Calculus in bladder.	200
A *medium tube*, Benoist No. 6, should be used for—	Wrist.	25
	Upper arm.	45
	Elbow-joint.	45
	Foot.	45
	Lower leg.	60
	Ankle-joint.	60
	*Thorax.	80
	Clavicle.	80
A *hard tube*, Benoist No. 7—8, should be used for—	Shoulder-joint.	80
	Knee-joint.	70
	Femur.	100
	Hip-joint.	160
	Spine.	100
	Pelvis.	180
	Skull (lateral).	120
	„ (antero-posterior)	160

* For those parts a heavier current will nominally be employed and intensifying screens interposed. so as to reduce exposure times very considerably.

NOTE.—Where intensifying screens are employed the exposure times quoted should be divided by the speed factor of the screens.

The negative must, however, be depended upon for critical comparison of results and clinical observation; and dependence upon prints would introduce unnecessary art into the radiographic process, already complicated by many uncertain factors.

For **foreign bodies** in the tissues or body cavities, the tube must be chosen of hardness suitable for the material of which the foreign body consists.

Some workers profess to ignore the necessity for variation in the hardness of tube used for radiography of different parts, and, working always with a medium tube, regulate the exposure (either current or time) in ratio to the density of the part.

For the best results, however, a tube should be chosen of a hardness relative to the part as tabulated.

II. Exposure.

The other factors having been more or less fully discussed in preceding chapters, it remains to consider the *time* of exposure necessary to secure good results.

Assuming that a tube of hardness corresponding to the part to be radiographed has been selected, the duration of exposure will depend mainly upon two factors: (*a*) the current supplied, and (*b*) the distance of the X-ray tube from the sensitive plate or film.

(*a*) **Current supplied.**—This is most conveniently spoken of for purposes of comparison in "Watts"; that expression of power being equivalent to the product of the quantity of current supplied, as expressed in amperes, multiplied by the electromotive force expressed in volts.

It will be readily understood that the more powerful the current supplied, the shorter will be the exposure required, other conditions remaining constant. The current supplied cannot, however, be directly calculated upon in deciding the time of exposure, since the efficiency of the high-tension generator and condition of the X-ray tube will materially influence the quantity of current actually passing through the latter.

This resultant current is indicated by the milliamperemeter in the tube circuit, and from the reading of that may be estimated the necessary time of exposure for any part, if the distance of that from the tube be fixed.

The product of the two factors—current and time—is thus a constant for any special part with standard tube and distance.

In the last column of the table of exposure times this product is set down for the conditions postulated, being expressed in milliampere seconds. (See note on page 22.)

The milliamperage being observed during the passage of the current, the average time for correct exposure of any part may from the table be readily estimated. If more current be passing, exposure will be proportionately shorter, and *vice versa*.

(*b*) **Distance of Tube from Plate or Film.**—As with all radiations, the effect of X rays on any object varies inversely as the square of the distance of that object from the source of the rays. Thus duration of exposure will vary directly as that factor.

A convenient rule for regular work is to set the antikathode of the X-ray tube at a distance of 10 inches from the nearest surface of the object to be radiographed. The table of exposures is based on work done under this convention, but there is some advantage in working instead with the tube at a standard distance—say 50 cm. (approximately 20 in.)—from the sensitive plate or film irrespective of the object interposed.

The **effect of an exposure** is thus seen to vary *directly as the current and the time, but inversely as the square of the distance.*

Variation of the hardness of a tube, as indicated by the alternative spark-gap or otherwise, has no such simple relation to the effect of exposure, but, with other factors constant, similar effect may be expected from

a	tube	of	2 in.	alternative	spark	in 30	seconds
or	,,	,,	3 in.	,,	,,	10	,,
or	,,	,,	4 in.	,,	,,	6	,,
or	,,	,,	5 in.	,,	,,	4	,,
or	,,	,,	6 in.	,,	,,	3	,,

Penetrative power must not be confused with actinic effect, although variation of exposure may compensate to some extent for failure to choose a tube suitable to the special part to be radiographed.

This compensation is practically confined to error on the side of softness, and can only be relied upon within certain limits.

Thus, rays from a hard tube will penetrate a hand, and fail to give definition or detail, however short the exposure may be; whilst a soft tube will fail to penetrate or define a hip-joint, though the exposure be ever so prolonged. An inexperienced worker should beware of being carried away by a "lust for speed" in exposure. For a time much was published in advocacy of very short, so-called instantaneous, exposures;

but, unless for special purposes, such practice has not become common.

Special apparatus for those very short exposures has been evolved by instrument makers, but experience in every-day work lends little or no support to the extreme measures suggested.

The exposures quoted in the foregoing table are found to give uniformly good results under actual every-day working conditions, and may safely be employed for all purposes for which radiograms are ordinarily desired.

With short exposures the same detail of structure cannot be obtained as with longer exposure, and this is especially important in considering every-day exposures for investigation of bones of limbs, many of them but partially ossified. Shortening the exposure of these to any marked extent would probably produce radiograms with fair outline, but with detail of structure—normal or pathological—quite indefinable. Thus the purpose of the process may be entirely missed through an attempt at its elaboration.

Where there is doubt as to the correct exposure for a certain set of conditions, it should be remembered that an over-exposed plate may, to a certain extent, be dealt with by precaution in development, whilst an under-exposed plate cannot be so remedied. Therefore, within reasonable limits, let the exposure be ample and development cautious.

Where, for physiological reasons, rapidity of exposure is desirable, that should be achieved by *reinforcement of the photographic effect* of moderate radiation rather than by direct increase of the intensity of radiation, and this is made possible by use of double-sided films and double intensifying screens.

In bone work this modification in technique is not called for, as in such cases a longer exposure has positive advantages; but in chest work it is desirable for reliable radiograms that exposure should not exceed one-fifth of a second, and by the use of double films and screens this is possible with a current of 20 milliamperes through a tube of about 4 in. alternative spark-gap.

In such work this photographic technique has practically revolutionised procedure, and has enhanced tremendously the utility of radiology in diagnosis; the details are described later, on pages 180 and 193.

An ingenious *guide to exposure* is furnished in the form of

a *slide-rule*, in which the various factors influencing time of exposure are charted on scales, which may be moved relatively to each other.

In use the two central slides are adjusted so that the figures corresponding to the existing distance, thickness of part, penetration and current are opposite to one another, and the index on the lower edge of the second slide will then point to the number of seconds required for the exposure.

Before setting the X-ray apparatus in action, a figure may be assumed as a probable milliamperage, and the product "M.A. seconds" may be estimated.

Detailed instructions for use usually accompany a slide-rule, and to a beginner this may serve as a useful guide until with experience he cultivates a reliable judgment for himself.

A similar guide will be found illustrated on page 126.

III. **Position of Patient and X-ray Tube.**

Much depends on the choice of a proper position of the patient and correct setting of the X-ray tube and sensitive plate or film.

No dogmatic rule can be laid down for all cases, as the conditions of choice will naturally differ for different parts, and the purpose of the exposure may also have to be considered.

Certain workers favour the position of the X-ray tube above the patient, almost to the exclusion of the alternative position of the tube under the patient, and *vice versa*, and much time has been spent in argument of the relative values of the two positions, whereas the truth is in compromise, each position being valuable according to the conditions of the case under consideration. Each position is discussed briefly in a later paragraph.

No exposure should ever be made before each point has been carefully considered and attended to; haphazard work can only result in disappointment.

In deciding the best positions the necessity for **steadiness** of patient and apparatus must be observed. It is of no use arranging a patient in an unsteady position, which he can only maintain by muscular effort, for that is almost certain to relax more or less and permit movement of the part exposed. Steady support of the tube was enjoined when speaking of tube stands, and is an essential readily understood.

A universal rule in deciding relative positions of X-ray tube, patient, and sensitive plate, is to **get the plate as near as possible to the object** or part of which a view is desired. If exposure must be made through the thickness of a part, then the plate should be placed on that side of it on which the lesion is suspected, for, as will be seen later, the parts nearer to the plate are defined relatively more clearly.

For each part of the body commonly radiographed a **standard position** should be decided on, and, unless special circumstances indicate otherwise, all exposures of the part should be made in that position for the sake of comparison with similar exposures either directly or in the mind of the operator.

Such positions are described and illustrated in a later chapter on "Diagnosis."

Clothing, Splints, Plaster, etc.—It is preferable to have the part of the body denuded of **clothing** when a radiogram is to be made of it.

Most textures obstruct the X rays but little, and outlines of bone can easily be defined through ordinary clothing. Such a view may, under special circumstances, be advisable and sufficient, but detail of structure cannot be defined under such conditions.

After a **splint** has been applied, a view of the part is often desired to ascertain whether displacement of the bone is accurately reduced.

It is, indeed, a rule with many surgeons that every fracture must be so viewed before it is considered to be "set." Through ordinary wooden or poroplastic splints a satisfactory view of a limb can always be obtained or a radiogram made; metal splints make either impossible, unless in a direction passing between the splints, although aluminium may prove trans-radiant enough to give a sufficient view of the relative position of broken ends or fragments.

On wooden splints strips of metal may interfere and limit the possible views, but means of avoiding this obstacle, as commonly met with in splints on the lower leg, may often be devised.

Plaster is always more or less a hindrance to X rays, and the strong adhesive plaster with a lead basis, which is employed by many to bind splints in position, is especially so, but the information desired can usually be obtained despite this. Even through a thick casing of plaster of Paris a radiogram of

a limb can be made, and will probably indicate clearly enough the position of fragments of a fracture or degree of reduction of a dislocation.

Dressings of preparations containing iodoform, bismuth, mercury, or lead are opaque to X rays, and should always be removed when possible.

Where such preparations have been absorbed into the skin, radiograms of the part may be affected by their presence.

When splints, plaster, or dressings have to be kept in position, and are interposed in the path of the rays, a harder tube than would otherwise be necessary should be employed, and it should be set a little closer than usual.

X-Ray Tube above the Patient.—This arrangement has many points in its favour for routine work by an experienced radiographer.

The tube and its connections are conveniently placed for observation and adjustment, its position relative to the patient may be directly inspected and regulated, and, above all, the direction of the rays is such as to involve the least risk of exposure of the operator. For bedside work, or on other occasions requiring portable apparatus, it is usually the only possible method. In such a case, the part to be radiographed should be supported on some firm, flat surface on which the sensitive plate may lie.

The part should be arranged on this in the most convenient position, and having turned downwards that aspect of which it is desired to have the most distinct view. Thus, if a picture of the sternum be desired, the patient should be placed with his face downwards; if a picture of the spine, he should lie on his back.

The necessity for centering the tube in its holder has already been emphasised in Chapter IV. (page 135), and the various devices for that purpose are there described.

The X-ray tube so centred must now be set directly over the centre of the part to be radiographed, and with the anti-kathode at a distance of about 10 in. from its upper surface, or 50 cm. (approx 20 in.) from the plane of the sensitive plate or film. This alignment is secured by viewing the tube and part from two positions at right angles, and adjusting the former till it is seen to be vertically over the centre of the part. A plumb-line may be dropped from the tube to guide its setting, or a centering device employed similar to one of those described on page 263.

The tube being thus set, the sensitive plate should now be placed under the part and the exposure proceeded with. Preparation and setting of the plate is discussed in a later paragraph.

X-Ray Tube below the Patient.—With the tube above it is necessary to set the tube and plate relative to the part to be radiographed, and trust that the view obtained will be that desired. With the tube below it is possible first to view the part on the fluorescent screen, and see the picture which will afterwards be impressed on the sensitive plate. With the screen illuminated the tube can be moved, the part manipulated, and the diaphragm adjusted to secure the view which best gives the desired information.

It is possible also to judge directly whether the tube in use is giving the requisite contrast in shadow to secure a good radiogram. These points adjusted, a sensitive plate may be substituted for the screen, and the operator may with assurance proceed with the exposure. The advantage of a table adapted for this position of the X-ray tube will now be understood, but the absence of a specially constructed table need not always prohibit exposure from below. An ordinary table may be used or a canvas stretcher supported at each end, and, with the patient on this, an X-ray tube fixed in an ordinary tube stand may be placed under and the exposure proceeded with.

For beginners this method has much to recommend it, and for some purposes it is preferable. Where screening is being carried on simultaneously or alternately with radiography, and no separate screening stand is available, it is naturally the most convenient method of working, and, with reasonable care, the added risk of exposure of the operator on account of the direction of the rays may be obviated or minimised.

Instead of being set by a preliminary screening, the tube may be centred under the part to be exposed by means of a plumb-bob suspended from a horizontal arm projecting across the table from an upright, which moves in synchronism with the tube box, as shewn in Fig. 180 on page 263.

The necessity for centering the tube in its holder—as referred to in the preceding paragraph—must here also be remembered.

An adjustable diaphragm is essential to secure the best results, but its usefulness may be limited with a tube set above the plate, since there is no opportunity of directly ascertaining the part actually illuminated. With a tube acting from below,

the diaphragm is fitted 2 or 3 in. above the tube, and serves to cut off all unnecessary marginal rays, which would otherwise produce cross shadows and blur the outline of the picture.

The diaphragm should be contracted so as to illuminate just as much as is really desired to be seen in the radiogram, and this may be regulated by preliminary screening. Inclusion of surrounding parts is of no value unless for localisation, and by restricting the area of exposure by the diaphragm much better definition of outline and detail is obtained.

With a large area of exposure, indeed, the image of the marginal parts is commonly so distorted as to be almost useless. This is due to the obliquity of the rays reaching them, as explained in an earlier section (see page 146). As there mentioned, in addition to oblique marginal rays from the target, there are irregular rays emanating from the glass walls of the tube, which further confuse the image if allowed to reach the sensitive plate or film.

Where it is necessary to view a large area, it is better practice to make two separate radiograms of adjoining areas, setting the tube appropriately for each, although, by use of the Potter-Bucky diaphragm, described on page 151, definition over a large area is considerably improved.

IV. The Sensitive Plate or Film.

Ordinary photographic plates may serve for radiography, and have been so used with satisfactory results.

Special plates are, however, manufactured, and give more uniformly good results. These plates are modified to give extra density of image, this being secured by coating them with more than one layer of sensitive emulsion. The ordinary sensitive emulsion is transradiant to X rays, hence superposition of several layers produces a cumulative effect. Makers endeavour by means of such reinforced emulsions to get a plate possessing more "stopping power," thus more definite pictures are obtained.

More recently the sensitive emulsion is coated on a flexible transparent base, thinner and lighter than the glass plate commonly used, and this combination of emulsion and base is known as a *film*.

Such films are separately referred to later, but, to avoid repetition, the following general remarks regarding sensitive

plates should be taken to include films, except where otherwise stated or obviously inapplicable.

It must be remembered that radiographic plates are sensitive to ordinary light, so that all manipulation of them must be performed in a carefully darkened room, lit only by green or red light, which should preferably be diffused by the use of some fabric or ground glass (see page 187).

Plates should be stored in a cool, dry place, and, if anywhere near a source of X rays, must be stored in a lead-lined box. It is much better, however, to store plates at some distance from the operating room, with the exception of those that may be required for immediate use.

X-ray plates were formerly sold wrapped, like photographic plates, in opaque paper, and packed in dozens in sealed card-board boxes, but now they are commonly sold packed in opaque envelopes ready for use.

There is a wide range in size, the three sizes most used, and therefore suitable to stock, being $4\frac{1}{4}$ in. by $3\frac{1}{4}$ in., known as "quarter-plate"; $8\frac{1}{2}$ in. by $6\frac{1}{2}$ in., known as "whole-plate;" and 12 in. by 10 in. It is a wise economy to use always the smallest plate that will include the desired view, and such practice will help to justify the use of plates of the best, though more expensive, manufacture. With this in view, the half-size plates, such as 10 in. by 6 in., should be remembered for radio-grams of the long bones. Where possible, the operator should decide in advance what plates he is likely to require, and before commencing other steps he should get those ready for use. If the plates are not already packed for use, the box should be opened in the dark room, preferably without any illumination, and each plate enclosed in paper **envelopes opaque to ordinary light.** Usually two envelopes are so employed—the inner one of orange colour, the outer black.

In placing a plate in the first envelope, it is necessary to know on which side of the plate is the sensitive film, and the absence of light may make this seem at first sight difficult. With a very little experience, however, the film side may be detected by touch, being soft and velvety by contrast with the side of bare glass, which is cold and slippery.

Another test suggested is by touching with the tongue, to which the film side is felt sticky; but touch alone is usually sufficient. It is useful in this connection to remember that plates are always packed in pairs, glass against glass, while

each pair has the outer film sides separated from the adjoining films by marginal strips of paper or thin cardboard.

The film side should be carefully dusted, then the plate placed in the orange-coloured envelope, with the film towards the plain side of the envelope—that on which an address would be written.

Then this envelope should be placed inside the black envelope, with its flap towards the closed end and its address side towards the same side of the latter. Plates sold in envelopes are so packed by the makers, and by this arrangement it can always be known towards which aspect the film side of the plate is turned.

This it is essential to know, for the plate must always be turned with this **sensitive side towards the X-ray tube.** If turned otherwise, the glass would interfere to some degree with the passage of the rays, and in interpretation of the radiogram confusion would arise in defining right and left sides of the view. This latter difficulty of interpretation from a radiogram alone, where conditions of exposure are not carefully observed, is no imaginary one, as anyone with experience will know; and especially is it so when a radiogram has to be expounded to one anxious but ignorant regarding such matters.

To obviate the difficulty, it is a good plan to interpose a **metallic object opposite one definite corner** of every radiogram. This may take the form of a small metallic clip adapted for the purpose, or a suitable piece of metal may be fastened by adhesive material to the face of the envelope. Metallic letters indicating right or left side or other information may be so employed. Where a system is adopted of numbering all plates by interposing metallic type in their exposure, the number may be printed always in one defined corner. This **numbering** may be done by combinations of separate numbers in solid or in stencil type, which are fastened on the face of the envelope by gummed paper just before exposure; and in the record book the exposure is entered under the corresponding number, thus facilitating reference. Instead of metal type, a label may be written on with an ink made of a suspension of a salt of bismuth in gum and spirit. On this may be entered any information desired besides its reference number, but, although the latter plan sounds enticing, the metal type is usually found more satisfactory.

A plate thus enclosed may be placed directly in position under or over the part to be radiographed, care being taken that its sensitive side, as indicated by the plain or address side of the envelope, is turned towards the patient, and thus also towards the X-ray tube. In most cases it will be found of advantage, however, to enclose the plate in a cassette or plate changer before placing it in position; with films the use of such an accessory is essential.

With the tube above and plate below, the superimposed weight of the part must be relied upon to keep the plate steady and in position, and in such a case a plate changer, as illustrated in Fig 128, should be placed under the part during the preliminary setting of the apparatus, so that a plate may be later introduced without disturbance of the patient.

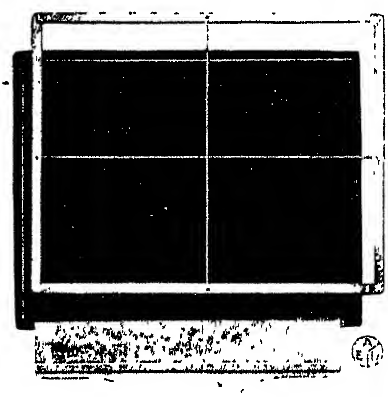


Fig. 128.—Aluminium Plate Changer with Cross Wires for Stereoscopic Work.

With the tube below and plate above, there is opportunity of exerting some pressure on the plate. Besides keeping it steady, this may serve to bring the plate in closer apposition to the bony or deeper parts of which a view is usually desired, which apposition is desirable so as to avoid distortion as far as possible.

The use of compressors in a similar way is discussed in an earlier chapter on "Accessory Apparatus."

To avoid another source of distortion, the plate must be held as nearly in a horizontal plane as the contour of the underlying surface will allow, unless for a special reason an oblique setting may be desirable. Where the contour of the

part is such that steadiness of the plate cannot be assured, a pair of adjustable supports, such as are illustrated in Fig. 129, may be employed. Those may also serve to support the fluorescent screen above a part during examination.

Exposure completed, the plate should be **removed at once** from the operating room, whether or not it be intended to proceed immediately with its development, since subsequent radiation, even from a distance, might otherwise seriously affect it.

Films are similar in essential properties to sensitive plates, but the sensitive emulsion common to both is in films coated upon a thin transparent flexible base of celluloid or similar

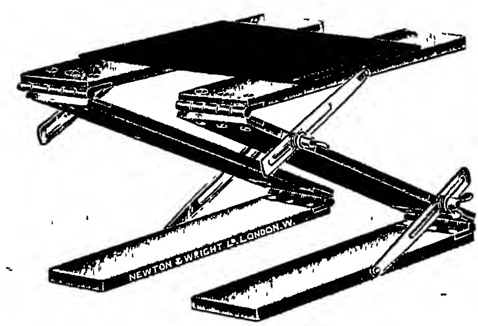


Fig. 129.—ADJUSTABLE SUPPORTS FOR PLATE OR SCREEN.

material, which is comparatively light, free from risk of breakage and less bulky.

Those advantages more than compensate for a certain degree of extra risk in handling them, and a careful routine technique, as described here and on page 193, obviates any danger of injury.

Single-sided films have a gelatine backing on the reverse side, but *double-sided* or "*duplitised*" films are also made, in which the gelatine backing is replaced by a second layer of sensitive emulsion. This gives two super-imposed photographic images, making a correspondingly denser radiogram, so that exposure may be reduced by about one-half.

It is especially important with those double films that *indicating marks*, as described earlier, should be imprinted upon the negative, as it may otherwise be impossible to determine how the film had been placed with reference to the X-ray

tube, and the interpretation of the radiogram may be hopelessly confused.

If reference marks be made by writing on the margin of films, care must be taken to write always on the same side of the film relatively to the patient during exposure.

Those double-sided films are particularly valuable for use with double intensifying screens, as described in the following section.

Most of the remarks in preceding paragraphs regarding sensitive plates may be applied to films, but certain special points regarding the latter demand attention. Great care must be taken in handling films before exposure, to avoid undue bending of them, and to avoid exerting any localised pressure on the sensitive emulsion, as in holding the film between finger and thumb, especially if the fingers be at all moist.

Pressure or moisture in such a case will inevitably produce "pinch marks" on the exposed plate, which will not only be unsightly but may tend to confuse diagnosis in a critical film.

It is also essential to avoid scratching of the sensitive film, and the procedure of unpacking the films and loading them into cassettes should be carried out with the greatest care.

The films as purchased are commonly contained in a box or package, made to open at one end, and each containing twelve films. Each film is covered with light-proof paper; the batch of twelve, sandwiched between two pieces of firm millboard, is further wrapped in three layers—of light-proof paper, damp-proof paper, and corrugated cardboard respectively, and are so carried in the containing box or package.

On opening a box or package, the contents should be allowed to slide out on the "dry table" mentioned later in discussing fittings of the dark room.

The three common wrappers should be removed, remembering to turn the films over, when necessary, always with their weight supported on the table. The top sheet of millboard should be placed under the bottom sheet, and the two now form a tray upon which the films can be lifted with safety, and from which, after films for immediate use have been removed, the remainder may be slid back into the box without further handling. This should be done with the covered end of the films towards the open end of the box.

The above details may seem superfluous, but such meticulous care is essential for the best results, and in practice is very

simple and rapid. The space given to it here is intended to impress similar care in all manipulation of the all-important, but inevitably delicate, sensitive emulsion of films or plates.

During exposure, unless the film may be laid on an even, firm surface, it is necessary to support it in some form of *cassette* or holder. This may be of the form illustrated in relation to plates in Fig. 128, or more commonly and conveniently it will be of the form described in connection with intensifying screens in the following section and illustrated in Fig. 130.

V. Intensifying Screens

Intensifying or Accelerating Screens are frequently used in the exposure of radiographic plates for the purpose of ac-

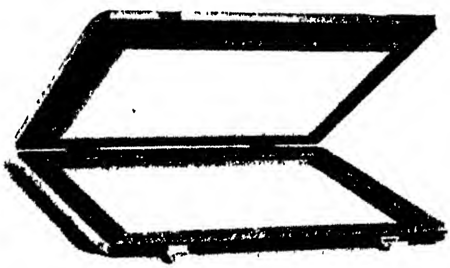


Fig. 130.—Cassette for Intensifying Screen.

celerating the exposure necessary for a given density of image, or conversely, to secure a denser image with the same exposure.

As already mentioned, the time of exposure necessary to secure an adequate image on a plate—known as the "speed" of a plate—depends upon the "stopping power" of the sensitive emulsion, but this, at the best, is very low, and over 90 per cent. of the incident X rays pass through the plate without producing any photographic effect.

Some of this lost energy may be utilised by intervention of a chemical having the property of absorbing X rays and emitting their energy as ordinary light, and screens are made by spreading on stiff paper (cut in standard sizes of plates) a thin layer of substance thus fluorescent under exposure to X rays. This usually has a base of calcium tungstate.

Such a screen is placed in close apposition to the sensitive plate, with the two sensitive faces turned inwards towards each

other, after all the wrappings of the plate have been removed. The film side of the plate being towards the tube, the screen will always be interposed between them. In exposure the actinic effect of the fluorescence produced on the screen is added to the direct effect of the X rays on the sensitive plate, and thus the effect of a given exposure is increased.

With films it is sometimes advised that the rays should pass first through the film before reaching the screen, the back of the film being thus turned towards the X-ray tube, but this practice is inadmissible with plates on account of the relative opacity of the glass, and the departure from uniformity in technique may lead to serious confusion in interpretation. The intervention of the screen between the source of the X-rays

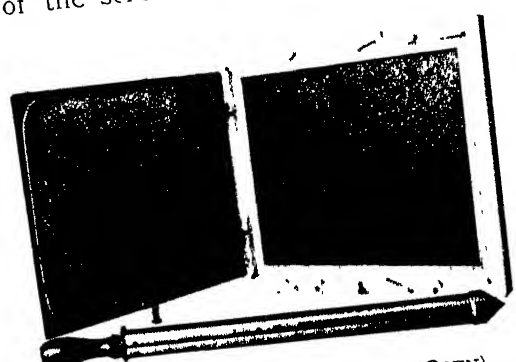


Fig. 131.—Pneumatic Cassette (Open).

and the sensitive emulsion may also serve a useful purpose, having a certain filtering effect which serves to check the softer secondary and scattered radiations of which the disturbing effect has elsewhere been pointed out.

With earlier screens it was advised that after exposure the screen should be left in contact with the plate for one or two minutes, as fluorescence continued after the rays had ceased to act, and for a similar reason such a screen should not again be used for at least fifteen minutes, so as to ensure disappearance of all remaining fluorescence due to the last exposure. This "after-glow" is less marked in later screens, which are much improved in quality, so that the above advice may practically be ignored.

In practice the plate and screen are placed in a special *cassette* (Fig. 130), in which the sensitive surfaces are firmly and evenly pressed together, so as to secure evenly distributed

effect. This *closeness of apposition* is a very important point, and the efficiency of the cassette should be carefully observed. *Pneumatic cassettes* are available in which an inflated rubber bag is used to secure adequate uniform pressure between the apposed plate or film and screen against the aluminium front of the cassette, and the contrivance is a very valuable one. (Fig. 131.)

The fluorescence from the screen being of the nature of ordinary light, special care must be taken to avoid all dust particles or stains between the screen and the sensitive emulsion.

Before charging the cassette in the dark room, the sensitive surfaces of both plate and screen must be carefully cleared of dust by a large soft camel-hair brush, care being taken not to scratch the surface of the screen. Dust specks embedded may be removed from the screen by means of a soft india-rubber or clean soft fabric, or, if this does not suffice, a little xylol, benzol or hydrogen peroxide may be used, the screen being dried thoroughly after cleaning; but a screen is very liable to damage in this way, and the presence of scratches, abrasions or stains may put an end to its efficient service.

The life of a screen will therefore depend very largely upon the care exercised in its handling. To avoid marking the surface by the edge of the plate, a screen should never be used with a plate smaller than the full size of the screen.

A certain degree of *graininess* in the resultant negative is almost inevitable in the use of intensifying screens, as the fluorescent layer is necessarily composed of fine particles, but this is uniform in distribution, and with modern screens *kept free from dust* this appearance does not detract from the diagnostic value of the radiogram.

Over-exposure may aggravate the tendency to graininess in screen negatives, but, on the other hand, an under-exposed negative is of very little value. Extra hardness of tube may also produce undue graininess, but fairly hard rays are essential to produce efficient fluorescence—with a spark-gap under 4 in. the advantage of an intensifying screen is largely lost.

Great *reductions in exposure* have been claimed by makers of intensifying screens, up to a ratio of 10, but it will be safer to assume that the exposure necessary with a screen will be about one-fifth that found requisite for a direct exposure under conditions otherwise similar.

Two *intensifying screens* may conveniently and advantage-

ously be used with a duplitised film, one being placed in apposition with each side of the film. Where two screens are so employed, the exposure may be reduced to one-tenth of the direct exposure.

In the absence of duplitised films two screens may be used with an ordinary single-sided film, but never with a glass plate.

For use with screens the black paper covering each film should of course be removed, as that would completely obstruct the fluorescence.

In **Teleradiography** acceleration of exposure is a specially desirable factor, since the X-ray tube is in this practice placed at a considerable distance—usually 80 in. (or 2 metres)—from the sensitive plate. This is done in order to eliminate to some extent the distortion of deeply situated organs which is produced by the divergent rays from a tube set at the usual distance—see Fig. 116 and adjoining text, also chapter on "Orthoradiography" (p 429). To secure adequate exposures in a short time at this distance would ordinarily require very strong currents, with special apparatus to suit, and the practical results attained hardly seemed to justify the expenditure. Thus, until intensifying screens were introduced, the method had been little utilised, although its value was recognised, especially for special purposes and in research.

VI. **Development.**

To one acquainted with development of ordinary photographic plates the after-treatment of exposed X-ray plates need offer no difficulty. In each case the impression made on the sensitive plate by exposure may be said to be "latent," since no change is visible in it until acted on by a suitable chemical solution or developer. This produces a chemical reaction in the sensitive emulsion wherever, and in proportion as, it has been acted upon by radiation. This results in a deposition of metallic silver from the compound suspended in the emulsion, and a graduated image is produced. The nature of this image is discussed later (see page 209).

The process of development is simple, if intelligent care be exercised in its direction; but much of the success of a radiogram may, nevertheless, depend upon it. Care and cleanliness are the two chief requisites for its successful execution. Many excellent manuals of photography are published which explain the *rationale* and details of the process of development, and

perusal of one of these will well repay anyone unacquainted with the subject, to whom the brief notes here set down may be insufficient as a complete guide.

The **time** occupied by development will depend naturally upon the length of exposure relative to the subject exposed, and also upon the strength and temperature of the developer. All of those factors should be *standardised* as far as possible, and there should certainly be no variation in routine work in the two latter.

The *temperature* of the developing solution should be 60° to 65° F.; lower temperatures will unnecessarily delay the process, whilst higher temperatures will interfere with the quality of the negative and may soften the emulsion so far as to loosen it from its supporting base.

Whenever possible, a temperature of 65° F. should be adhered to, for only thus can the maximum amount of detail and definition be obtained.

With a standard developer and with conditions of development likewise standardised, it is possible to criticise the preliminary exposure and so control future exposures.

With proper exposure a plate should be allowed about six to ten minutes to develop, a film about five minutes. It is possible to complete development more quickly with good results, but little is gained by rushing the process, and much may be lost. With over-rapid development much of the finer detail in the picture is inevitably lost, whilst there is danger in prolonged development of chemical fogging, or changes in the film due to prolonged immersion.

Any of the ordinary **developers** may be used, but it is well to follow the instructions which are always published with plates or films as sold, and which vary slightly for different brands of manufacture.

The undernoted developer and notes on its use are taken from directions issued by the makers of a well known X-ray plate, and may serve as a type of such solutions :—

METOL-HYDROKINONE.

Metol - - - - - -	20 grains	2 grammes
Hydrokinone - - - - -	80 ,,	8 ,,
Sodium Sulphite (crystals) - -	1000 ,,	100 ,,
Sodium Carbonate (crystals) -	1000 ,,	100 ,,
Potassium Bromide - - -	10 ,,	1 ,,
Water to - - - - - -	20 ounces	1 litre

When making up the above developer the Metol must be dissolved first in about 8 ounces (400 c.c.) of warm water, and when thoroughly dissolved the Hydrokinone is added. The Sodas and Bromide are then thoroughly dissolved in a further 8 ounces (400 c.c.) of water and the two solutions mixed together and made up to 20 ounces. It is most important that each ingredient be allowed to dissolve thoroughly before adding the next. The developer is then allowed to cool, and to ensure the best results it should be used at a temperature of 60° F.

Caution.—If the Metol is not allowed to dissolve thoroughly before the other chemicals are added, it will crystalise and be precipitated in the form of granules. Should any of these granules settle on the plate during the process of development, small black spots with soft edges are likely to appear on the negative in those places where the granules have settled. Moreover, in using a developer made up improperly the full strength is not available, and such conditions may account for failure to obtain the best possible results. A freshly made developer should be almost transparent in appearance and free from colour.

The developing solution having been used for about half-a-dozen plates in succession should be thrown away and a fresh supply obtained, otherwise it becomes oxidised by exposure to the air and ceases to yield clean brilliant results. A developer that has been used for a number of plates must on no account be kept for future use. Oxidation having commenced will continue until the solution ultimately becomes nearly black and quite useless. The freshly made Metol-Hydrokinone developer, if kept in properly stoppered bottles, will keep in good condition for a considerable time.

The salts for such a developer may conveniently be obtained in packages which contain the requisite quantities and proportions for solution in a given quantity of water. This plan has much to recommend it, but is decidedly expensive when much work is being done.

A *dark room* is essential for the development of exposed plates or films as well as for loading cassettes and other manipulation of unexposed sensitive material. Much depends upon the proper construction and arrangement of the dark room, and scrupulous cleanliness must be observed in all its processes. Fig. 132 suggests an arrangement in plan which meets most requirements. The room should have good ventilation, specially arranged, or windows should be easily accessible and kept open when work is not actually in process.

The room must be carefully **darkened,** unless for a non-actinic light, which for general illumination is most conveniently derived from a ceiling reflector lamp, as illustrated in Fig. 133. This throws its light upwards through a sheet of "safe-light" glass, and the light is reflected from a white ceiling and light-coloured walls. For judging density of negatives, a specially designed dark room lamp should be arranged over the de-

veloping bench. Fig. 134 shews an efficient design, which may also serve for exposing bromide prints (p. 201).

The source of light in this lamp is set in the upper part of the lamp, which is of metal with a metal shutter, the inside surfaces being enamelled white. In the bottom part is an inclined reflector—usually of opal glass—which reflects light to the outside through a glass window.

For use in the dark room this window is covered by two panes of coloured glass, yellow and blue, which transmit a red light, non-actinic in character and "safe" to work by while

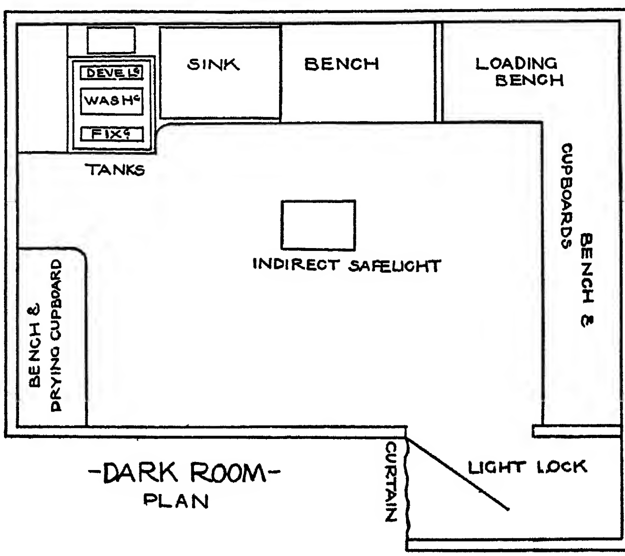


Fig. 132.—Plan of Dark Room.

manipulating sensitive plates or printing paper. Neither of those should ever be needlessly exposed to any light, however "safe."

Running water is necessary for serious work, led into a *deep sink* for washing purposes. A further supply of *hot* water for cleaning dishes, film holders, etc., will be a great convenience.

Near the sink must be a *bench* draining into it, upon which the work of developing and fixing plates and prints may be carried on. Over this bench should be a *shelf* for measures and other dishes which may have wet drips from them, and

under the bench may be arranged shelves and racks for developing trays, etc.

Well removed from the locality of those wet processes, it is necessary to have a *table for "dry" work*, on which unpacking and loading of unexposed plates, films and papers may be carried out; the risk of soiling this table or splashing the sensitive material handled on it must be obviated by all means. Another *table* is necessary for weighing out chemicals and other odd processes, and a good *cupboard* should be supplied for storing plates, films, printing paper, etc.

Tray Development.—Plates or films may be developed by the older method in flat dishes or trays of porcelain, glass or

Fig. 133.

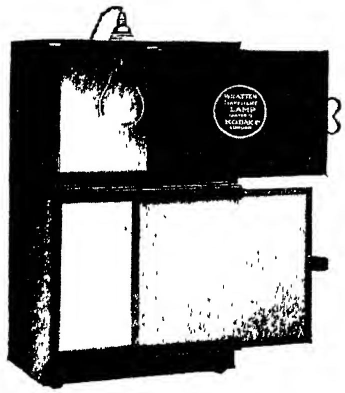


Fig. 134.

DARK ROOM LAMPS.

composition; though films are more conveniently dealt with by the tank method described later, and for duplitised films tanks are practically essential. The following instructions regarding plates may be equally well applied to films, but extra precautions will have to be taken in handling the latter.

An experienced worker will reduce the steps to routine by standardisation of all factors so far as possible, and results will improve accordingly, but the inexperienced worker should first pay detailed attention to each step in sequence, observing the variations here described, so as to obtain an intelligent appreciation of the different factors involved. Later, in describing the tank development of films, a standard method is more precisely indicated.

The light being arranged for "safety," take the plate out of its envelopes, and gently remove any possible specks of dust from its surface by means of a soft brush or by blowing. Place the plate, film upwards, in a dish of appropriate size and shape.

Rapidly **flood the plate** with the prepared developer, taking care that the surface of the film is uniformly wet, and that no air-bells are allowed to remain upon it. The former point is best attained by raising one corner of the dish and pouring the developer from that corner, the latter by removing the air-bells with the finger if necessary.

Keep the fluid moving over the face of the plate by giving to the dish a continuous rocking motion. Mechanical rockers may be bought for this purpose.

Watch the plate carefully for the first minute or two, since an over-exposed plate may flash up very rapidly, and must at once be checked.

If no change appear within the first two minutes, it is safe to **cover the developing dish** so as to protect the plate from the light, since even the coloured light may affect it if freely exposed for any length of time.

For the purpose of covering the developing tray, it will be found most suitable to use a papier maché tray slightly larger in size. Metal trays, even when enamelled, are liable to become oxidised and specks of rust may fall on the plates (or prints) below.

On a correctly exposed plate, after about one minutes' development darker patches should begin to appear, and should gradually and slowly form an image. Meanwhile the rocking motion should be kept up and the progress of development occasionally observed.

When the upper surface appears fairly dark, raise the plate and view its under surface. With an ordinary photographic plate completion of development is commonly judged by viewing the plate held between the observer and the light. This method may also be employed with radiographic plates, but development of the latter must be carried further than with the former. Development with these must be carried, as it were, through the extra thickness of the film, and the criterion of completion is seeing the black shadows plainly marked on the back of the plate.

If before that time the white parts of the plate begin to assume a uniform dirty greyish tint, it may be implied that

a "chemical fog" is setting in, and development must be stopped.

Short of such occurrence **over-development is not readily reached,** and a beginner's timidity will more often lead to the opposite mistake.

Commonly, with full exposure first details appear in 20 to 30 seconds and complete development in 4 to 10 minutes.

In the absence of effective standardisation of time of exposure and other steps in the process, it is not possible to ascertain in advance the time requisite for proper development; and, in such a case, valuable time may be saved by regulating **development by the clock,** by the so-called "**Watkins' Method.**" Undue handling of the plate is also thereby obviated.

It is found that the time taken for complete development of a plate is approximately twelve times that which elapses before the appearance of the first details of the image.

A special **dark room clock** is most convenient for this process. As shewn in Fig. 135, this carries a seconds hand and a minute hand pivoted centrally, and an indicator on its outside circumference which may be set as required. The numerals denote minutes for the big hand and groups of ten seconds for the seconds hand.

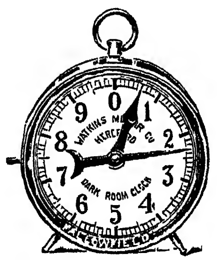


Fig. 135.—WATKINS' DARK ROOM CLOCK.

Both hands are brought to 0 by a stop action, and the clock is started by pressing a lever when development commences. When first details of image appear on the plate the time in seconds is noted, the clock being stopped for an instant if necessary. This time is multiplied by twelve and the indicator is set opposite the point on the dial which the minute hand will reach on completion of that time (reckoned from 0).

When the minute hand is seen to reach that point development may be expected to be completed.

A signal bell may be arranged to give warning of the point being reached.

Errors in Exposure.—In an **over-exposed** plate changes appear very rapidly after development is commenced.

In such a case pour the developer back into its original container and wash the plate rapidly in running water under the tap.

Then dilute the developer with about an equal quantity of water and resume development.

If over-exposure be suspected, it is well to commence with a weak solution of developer, and have some stronger solution at hand to add if development prove slow.

If **under-exposed,** the plate shews the changes due to development correspondingly slowly.

It is not well to attempt acceleration by strengthening the developer; additional time for development is the obvious and safest remedy, but a satisfactory result need never be looked for with a plate which is under-exposed to any extent.

Probably the best possible result will be obtained by diluting the developer, covering the dish, and allowing development to proceed for a long time. This method, at least, allows the operator to leave development to proceed in safety while he attends to something else. When the dark parts shew quite black at the back of the plate, it is needless to prolong the process further.

Various modifications of, and additions to, developers are suggested to compensate for errors in exposure, but all these measures are very partial in their effect or utility, and the X-ray worker is not recommended to dabble with them.

No after treatment will fully compensate for errors in exposure. All possible attention should therefore be paid to the latter factor, and the development should be cautious but straightforward, as described. An over-exposed plate will be very dense and will fail to shew fine detail or contrast between its darker and lighter parts, being termed "flat"; while an under-exposed plate will rather exaggerate contrast, but will lack detail or depth, being termed "thin" in quality.

As mentioned in the notes following the developer formula on page 187, it must be remembered that the developing solution becomes gradually exhausted as its chemicals are used up in the process of development, and further use of such a developer will not only prolong the time required but will produce poor negatives.

In tray development, as described above, enough solution should be made up to complete the work in hand, and after use should be thrown away.

In tank development, described in the following paragraphs, the developer is in such large excess that exhaustion is slow if the tanks are kept covered.

Tank Development.—Plates may be developed by the tank method, but it is more specially applicable to *films*, and the technique is here described as for the latter.

The tanks employed may be of varying design and material, but each must be of size sufficient to contain fluid for the complete immersion of the largest size of plate or film employed, whilst that stands, or is suspended vertically, in the tank.

Each tank is for a specific purpose, and the developing and fixing tanks must on no account be substituted for each other or the result will be disastrous; similarity in size makes such a substitution an open possibility.

In addition to the two tanks for chemical solutions (developing and fixing), other two for water may be used, as shewn

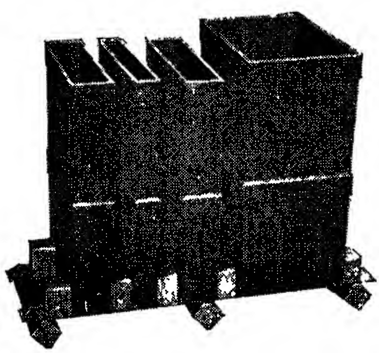


Fig. 136.—Set of Tanks for Developing, Rinsing, Fixing and Washing Films (or Plates).

in Fig. 136, one for rinsing after development and a larger for final washing after fixation; or the large tank may be used for rinsing and the final washing be carried out in a special tank or sink arranged with running water.

In such a washing tank the outlet must be at the bottom, so as to draw off the sediment which accumulates there. An adjustable tap may be so arranged or a siphon (as in Fig. 137).

If "unit" tanks of light material be employed, they may be set into a large sink containing water at a definite temperature capable of regulation, so that the whole process may be carried out at a standard temperature, and each unit may be easily replaced by a similar one containing fresh solution, when that may be required.

The vertical position of the emulsion surface obviates the possible settling of deposit on its surface, so that movement of

the solution (as in tray development) is unnecessary, and the danger in handling the film or plate is minimised.

For convenient handling a film should, on removal from its exposure cassette, be placed at once in a metal *film holder* of appropriate size, as seen in Fig. 138, on page 198, and in Fig. 141.

From their method of use in the tank process those are commonly referred to as "*film hangers*," the projecting pieces being designed to rest on the edges of the tank opening whilst the film is suspended in the contained fluid.

A wet film should never be handled, unless supported in such a rigid frame, until the final stage of drying is reached.

Developer in the tank should be prepared in the manner already described (on page 186), the only difference between tank and tray development being the increase in quantity, which in the tank must be sufficient to immerse completely each plate or film during development.

The temperature of the solution having been adjusted to 65° F., each film in its hanger is dropped into the tank, and, suspended by the projecting parts of the hanger, remains immersed for five minutes or such other time as has been found proper for any special conditions of work.

Several films may thus be developed simultaneously, and on completion of development may similarly be passed into the second tank for rinsing, then into the fixing solution, and finally to the washing tank. The top bar of the holder need only be handled, and the process is thus rendered more simple and cleanly than in the older method by use of trays. With ordinary care the hands need never be wet by any of the solutions, thus obviating the use of gloves, which are otherwise necessary for the protection of the skin in continuous work.

Care must be taken that drippings of the fixing solution do not reach the developer or, indeed, any place or part other than its proper tank or the succeeding washing tank, but such contamination by drops or splashes is less probable with tanks than with trays, if reasonable care be exercised in the process.

Fixing.—Development being completed as described, **the plate or film should be rinsed** to rid it of developer. Otherwise chemical action between that and the fixing solution may result in a coloured stain, seen as red by transmitted light and green by reflected light. This is a most annoying fault in a negative, but should never be encountered in careful working. After

rinsing, the plate or film should be **immersed** in a fixing bath, as recommended by the makers of the plates or films in use.

This consists of a solution of sodium hyposulphite, commonly spoken of as "hypo,"—with various additions of secondary importance

A typical solution is the following:—

Hypo - - - - - - -	1 lb.	400 grammes
Potassium Metabisulphite - -	½ ounce	13 ,,
Water to - - - - - -	80 ounces	2 litres

If the fixing bath is required for immediate use, it is suggested that the potassium metabisulphite be dissolved before adding the hypo, but hot water should not be used for the purpose.

Under ordinary circumstances the hypo should be dissolved in a small quantity of hot water and cold water added; then, when the hypo is fully dissolved and the solution is cold, the bisulphite, dissolved in a few ounces of water, should be added.

A stronger solution of hypo would probably act more rapidly, but has a tendency to soften the film and cause frilling

The negative should be kept in the fixing bath (preferably in motion if in a tray), till all the unaltered silver bromide is seen to be removed from the emulsion. This is seen in the disappearance of the last trace of the opaque whiteness of the original film, and is best judged by holding the plate in such a position that the light of the lamp is reflected from it, preferably with something black behind it. In this position the plate should appear uniformly black.

A partially fixed plate should on no account be examined by daylight, or stains will appear on the film which cannot afterwards be removed.

Fixation should be complete in 8 to 10 minutes, but it is better to leave the negative in the fixing solution for an equal time after the process is thought to be ended, so as to ensure its thorough completion.

It is a good plan where trays are in use, and when a number of plates are being "put through," to have two dishes of hypo solution, reserving the second dish for a final immersion of each plate after it appears fixed in the first.

A fixing bath must not be used for too many negatives, or its exhaustion will lead to unsatisfactory results.

When fixation, as noted above, takes about twice the time required in a fresh solution at the same temperature, the limit

of efficiency may be assumed to be reached. A fresh solution should take the place of the exhausted stock, but under no circumstances should fresh hypo be added to strengthen a partially exhausted bath.

In very **warm weather** or in **hot climates** it is advisable to add to the above fixing-bath of hypo ½ **oz. of alum**, dissolved in hot water and filtered; and possibly also ½ oz. of glacial acetic acid or 1 oz. of citric acid. Further, after washing the fixed negative, it should be immersed for 5 to 10 minutes in a bath of alum as under:—

Alum - - - - -	60 parts	or	1 ounce
Water - - - - -	1,000 parts		16 ounces

Or in a mixture of formalin and water, 1 to 10.

This is to prevent frilling of the film, which may follow undue softening, but under ordinary conditions this is unlikely to occur if the bath be kept acid in reaction, and this should be tested occasionally by litmus paper.

Washing.—After being fixed, the negative must be thoroughly washed in running water. If this be properly circulated, so that all parts of the negative are continually exposed to fresh water, the process should be complete in half an hour. If running water be not available, but only frequent changes in a large dish, longer time must be allowed—up to two hours or more. Prolonged washing can do little harm, and washing must be thorough to insure preservation of the plate. If the hypo be not thoroughly removed, it will later crystallise on the plate and spoil it for further use. Preparations are sold under the name of hypo eliminators, in a bath of which the plate may be immersed after fixing and a brief washing, and after which a further washing for a short time only is required. Where a negative is urgently required, its completion may be so hastened; a simple method being, after one minute's washing in water, to treat the negative with a weak solution of potassium permanganate until the colour of the solution ceases to be discharged. The negative will then be ready for drying—three or four minutes only being required for the elimination of the hypo. Water is, however, the best eliminator.

Fig. 137 shews two types of washing tank for plates, the washing water being supplied from a convenient tap and being drawn off from the bottom of each tank by the siphon shewn. This prevents deposition of salts in the tank and keeps a

constant bath of clean water. A similar arrangement for films should be made in a deeper tank.

Drying may be done in any place free from dust and moisture, but heat must be employed only with great care. Plates may be set on edge, and supported at an angle against a vertical support, preferably with the film side downwards to save it from dust; or they may be placed in a suitable rack, which supports them upright, like that illustrated in Fig. 138.

If time presses a plate may, after thorough washing and short time of draining, be immersed in a bath of alcohol, after which it will dry rapidly. Besides the expense of this, there

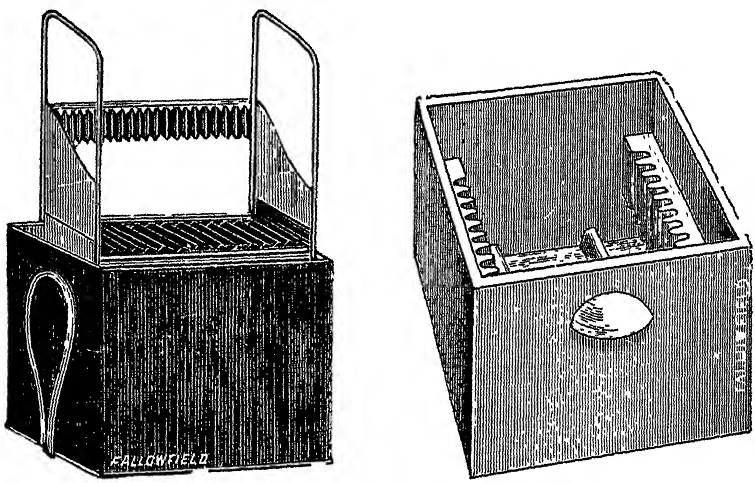


Fig. 137.--X-RAY PLATE WASHERS.

is a danger of unequal drying and contortion of the sensitive emulsion, and a celluloid film must never be so treated. In ordinary work there is no necessity for it, as plates can be examined conveniently while wet, and then allowed to dry naturally.

Each plate may be examined and a report made upon it after it is but partially washed. The washing may then be resumed and continued as required.

To obviate spotting, it has been recommended that after washing, the water should be carefully mopped from the emulsion surface with absorbent cotton, and that drops should be so removed as well from the glass sides of plates. This must, however, be done very carefully, or marks may be

produced which will be more annoying than the possible spots produced by evaporation of undrained drops of moisture.

Films should be set up to dry in their holders, supported in a rack with slots, as illustrated in Fig. 138. After a time they should be removed from the holders and suspended by clips along the edge of a projecting shelf, or on a line of wire or cord. Left in the holders the edges will be found wet long after the body of the film has dried, or else the film may adhere to the holder. When a number of films are suspended, sufficient space must be left between adjoining films to obviate touching if movement should occur, as by a draught of air, otherwise the films may stick together with disastrous results to both concerned. Such draughts of air should be avoided so as

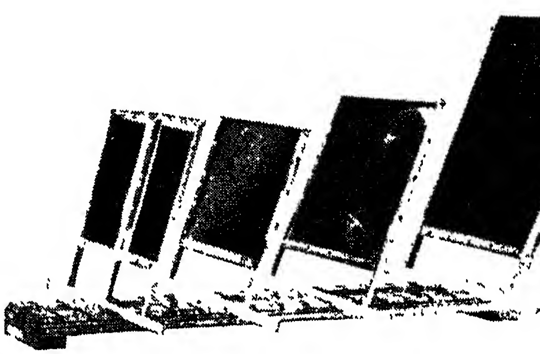


Fig. 138.—X-RAY FILM DRYING RACK.

to secure uniform drying, and no sudden changes of temperature must occur. Under ordinary conditions negatives will dry most satisfactorily in a warm dry atmosphere where the air is changing.

Temperatures over 90° F. should be avoided, as their effect on the emulsion would be injurious.

After a film is removed from it, each *holder* should always be thoroughly *washed* in hot water, leaving it if possible to soak over night, and hanging it to dry in the morning.

Before again using a holder a stiff brush should be used along the inside of the hinge and along the grooves, so as to remove any residual hypo which may have cystallised as a result of washing with water at a lower temperature than the hypo bath or of insufficient washing. Failure to remove such hypo will obviously result in damage to the film next dealt with in the holder.

Intensification of thin plates and **reduction** of over-dense plates may be effected to some extent, but is not to be recommended for X-ray work. By these processes, applied evenly to the whole plate or in judiciously selected patches, astonishing results may be obtained by professional photographers when employed in improving or "faking" plates, but this is quite outside the work of medical radiography and should not be attempted. If a plate be not satisfactory, the exposure should, if possible, be repeated on a fresh plate.

There may, however, be occasions when it is impossible, or very inconvenient, to reproduce the exposure, and in such cases appropriate chemical solutions may be employed to act on the metallic deposit forming the image on the negative, so as to increase or reduce its density as required. Before either process is attempted the negative must be fixed and thoroughly washed to remove all traces of hypo.

For *intensification* various solutions are employed. In each case the negative is subjected to a preliminary "bleaching" in a solution such as A, noted under, and after rinsing is immersed in a second solution, such as B, until the requisite density is attained.

INTENSIFYING SOLUTION.

A.

Mercury Bichloride	... ..	100 grains	23 grammes
Potassium Bromide	... ..	100 ,,	23 ,,
Water to	... ...	10 oz.	1,000 c.c.

B.

Sodium Sulphite (crystals)	..	2½ oz.	250 grammes
Water to	... .	10 oz.	1,000 c.c.

The above is not a very strong intensifier, but where stronger action is required a satisfactory radiogram is not likely to result, and no intensification need be attempted if a noticeable image is not present to start with.

Reduction is more likely to be called for in the ordinary course, and a satisfactory result is more probable, since over-exposure or over-development may have produced undue density overlying, as it were, a satisfactory image.

Various solutions are employed, but for general purposes a mixture of the two solutions noted under is probably as satisfactory as any.

REDUCING SOLUTION.

A.

Potassium Ferricyanide ...	15 grains	1 gramme
Water	1 oz.	30 c.c.

B.

Sodium Hyposulphite ...	1 oz.	30 grammes.
Water	32 oz.	1,000 c c.

A and B to be mixed for use.

The process must be observed whilst the negative is in the reducing solution, and the negative must be removed and thoroughly washed whenever the desired degree of reduction is attained. Without careful observation the reduction is very liable to be carried too far.

Storing Radiograms.—If a negative has not already had a number printed on it during exposure, it should, for the sake of reference, be numbered before being stored. This may be done by affixing a written label to it, or by writing with white ink on the margin or other blank part of the film.

To avoid scratching of the film, each negative may be placed in a soft paper envelope, on which is written its number and any desired particulars; the age of the subject being a most important particular to have attached.

Plates may be stored in batches in the boxes in which they were originally contained, or in the largest-sized boxes; and a rack, suitably divided, may be designed to hold the more recent exposures, so that they are handy for reference.

Films have a considerable advantage as regards storage, as they require only about one-sixth the space required for an equal number of plates. Immunity from breakage and comparative lightness in weight add considerably to this advantage. Films may even be filed with the clinical records of cases where critical reference may be anticipated.

A record book should be kept of all work done, and in this may be entered such details of cases, notes of process, copy of report, and remarks as may be thought fit.

If any variation of apparatus or exposure be tried, a note of this should also be made; but when an operator comes to make all exposures on a standard basis, it seems unnecessary to repeat the data for every exposure made.

A simple form of record book for use in regular work may have entries made under the following headings :—

Date.	Patient's Name.	Age	Sent by.	No. of Plate.	Part affected.	Lesion.	Query.	Treat-ment.	Result and Remarks.

Prints.—It should be remembered that the "negative" is always the most satisfactory and most reliable picture for report or reference. Some of the detail and definition is inevitably lost in printing, and the entailed reversal of sides of the picture is often confusing. But duplicates of the radiogram may be required, or the record may be desired in a more portable and convenient form, and for these or similar reasons prints are made.

Ordinary **silver printing-out papers** make suitable prints where sunlight is available. The paper clamped behind the plate in a printing frame, as described later for bromide prints, is exposed to daylight until it becomes of a colour a little darker than is finally desired. Printing should not, as a rule, be done in direct sunlight, but rather by diffused light. The former is more rapid, but tends to reduce the contrasts of the picture, whilst printing in weak light tends to increase them; and efforts are usually directed to secure the latter condition in a radiogram.

After being printed, the paper is submitted to a suitable toning process, and is then fixed, or a "self-toning" paper may be used which requires fixation only. The details of these processes differ somewhat for different classes of paper, and with each packet sold are enclosed printed instructions as recommended by the makers for that special paper. These should be followed, and are usually explicit enough to render superfluous any further remarks here.

Bromide paper is especially suitable for radiographic work, since it gives strong contrasts, and can be printed at any time of day or year by exposure to gas or electric light. Unlike the silver papers, no immediate change can be noted on this paper after exposure, but, like a sensitive plate, it requires development to make the impression visible. Thus there is no direct means of regulating the duration of exposure, and this is a difficulty which can only be overcome by experience in working.

Bromide papers are extremely sensitive to light, and must therefore be manipulated entirely in the dark room, like sensitive plates.

More light may be permitted than with the latter, and the yellow glass alone in the lamp will be sufficient for safety, while giving more general illumination for moving about and working in the dark room.

In X-ray work bromide prints are usually made **in contact** with the plate, unless when the print is a reduction or enlargement in size of the radiogram. The papers usually curl a little when unpacked, and this may serve to indicate the sensitised side of the paper, as that is always to the inside of the curl.

This side is placed in contact with the film side of the plate, and the two clamped together in a printing frame of suitable size. Artificial light must be used for making bromide prints, as most papers are much too sensitive for daylight printing.

Reductions or **enlargements** may also be made from radiograms on bromide paper. The latter are seldom called for and the nature of radiograms do not suit the process, but reductions may be very convenient.

In the process the picture may be sharpened and contrasts made greater; prints may be made while the plate is still wet, or even before it is washed, thus saving time in furnishing a record to the surgeon. A further advantage is suggested in the section on stereoscopy and in localisation of foreign bodies. Special apparatus is necessary for the process, which some may reckon more suitable for a professional photographer, but the technique is simple and may easily be mastered by anyone when the circumstances of his work renders it worth while.

Correct duration of exposure will depend upon three factors —intensity of light, distance of paper from the light, and character of the negative.

The first can be made standard by always employing the same light for printing—say, a 16 candle-power electric lamp or a certain number of gas burner. The distance can also be made standard, or at least in fixed ratio, the exposure required varying as the square of the distance. For small negatives such as quarter-plate size a distance of 1 foot is convenient, at which distance from a 16 candle-power lamp an exposure of about ten seconds should be sufficient, but the time varies for different sizes and makes of paper. Larger negatives must be kept farther away, or must, with the apposed printing paper, be kept moving from side to side and up and down during the exposure, in order to secure even illumination.

Printing at a greater distance from the light is to be recommended, since this tends to increase the contrasts, which result, as already stated, is usually desirable. The third factor—character of the negative—is one constantly varying in

different negatives, but should vary less as the worker is more experienced in exposure and development of plates.

The density or opacity may be judged by examining the plate held between the eye and a distant light, a sky of white clouds forming a convenient source of diffused light for the purpose. A denser negative, of course, demands longer exposure in printing from it.

Only by trial, however, can a worker hope to get an intelligent idea of this printing process, and if he cannot afford the time to experiment on it, he had better entrust his printing to a practised hand.

The lamp shewn in Fig. 134 serves well for exposing bromide prints.

If the upper part be fitted with a front of flashed opal, exposure may be made by withdrawing the metal shutter, and closing the shutter will quickly restore dark room conditions when required. If the lamp be kept in a fixed position (or its position be marked) a scale of distances from its front may be marked on the adjoining wall or bench, thus supplying a ready reference in arranging exposures.

Various developers may be used, but, as with plates and silver prints, the instructions enclosed with the special brand of paper should be followed. Pyro developers are not suitable, on account of colouration produced in the paper.

Correctly exposed a print should take two or three minutes to develop. The following developer and notes are from the instructions enclosed by the makers of a well known and widely used paper:—

> Having made the exposure, immerse the paper face upwards in water until thoroughly soaked, then drain off *and immediately* flow the developer evenly over the surface. *Insufficient soaking is the cause of air bubbles, producing white spots.* (For small prints it is preferable to flow the developer over the exposed paper.)
>
> We advocate Amidol as being the most reliable developer for general purposes, although any other may be used.

Amidol Developer.

Amidol - - - - - - - - -	50 grs.	3 grammes
Sodium Sulphite (cryst.) - - -	650 ,,	40 ,,
(or Anhydrous Sodium Sulphite, 325 grs.)		
Potassium Bromide - - - -	10 grs.	0·75 ,,
Water to - - - - - - -	20 ozs.	500 c.c.

This developer should be used within three days of mixing.

Metol-Hydrokinone Developer.

Metol - - - - - - - -	50 grs.	3 grammes
Hydrokinone - - - - - -	15 ,,	1 ,,
Sodium Sulphite (cryst.) - - - -	500 ,,	30 ,,
(or Anhydrous Sodium Sulphite, 250 grs.)		
Potassium Bromide - - - - -	10 ,,	0·75 ,,
Potassium Carbonate - - - - -	100 ,,	6 ,,
Water to - - - - - - - -	20 ozs.	500 c.c.

Dissolve the Metol in the water first. *This developer keeps well.*

The same solution may be used for two or more prints in succession.

As soon as development is complete (which for a normal exposure should take about two minutes), the print should be transferred, without washing, to either of the following *fixing baths*, where it should remain for at least five minutes.

Fixing Bath.

Sodium Hyposulphite - - - - -	4 ozs.	100 grammes
Water to - - - - - - - -	20 ,,	500 c.c.

Or the following **Acid Fixing Bath** may be used :--

Sodium Hyposulphite - - - - -	4 ozs.	100 grammes
Potassium Metabisulphite - - - -	200 grs.	12 ,,
Water to - - - - - - - -	20 ozs.	500 c.c.

NOTE.—Thoroughly wash after fixing.

Proper fixation is essential, both for the purity of the prints and to ensure their permanence. To ensure complete fixation the print should be immersed face downwards in the fixing bath.

To preserve the purity of the whites, exposure should in all cases be sufficient to obviate necessity for prolonged development, and full density should be attained with most papers in about two minutes; longer development means, as a rule, precedent under-exposure and an unsatisfactory print. Care should be taken to handle the bromide papers as little as possible, as pressure or friction caused by careless handling will give rise to black markings during development. These may, however, generally be removed by gentle application of a tuft of cotton wool moistened in spirit.

To prevent uneven development of large prints, it is as well to soak the paper in water before development, care being taken to remove all air-bells; otherwise the process is similar to that described for plates on page 190.

If general fogging or over-density be feared from longer development, and more detail be desired in certain parts, this may be secured by applying to those parts fresh full-strength developer, conveyed on a brush or cotton wool.

Attention may by the same process be focused on the essential parts of a print, but such procedure may readily border on "faking."

Errors in exposure cannot be compensated in development, as the action of the developer seems to reach a certain stage dependent upon the condition of the exposed paper and there stop. Especially is this true of the Amidol developer.

After development and fixation prints should be washed for at least half an hour in running water. If the water be not running the prints must be kept in constant motion, and frequent changes of the water made, special care being taken to prevent the prints sticking to each other.

To facilitate the process of washing and obviate injury to

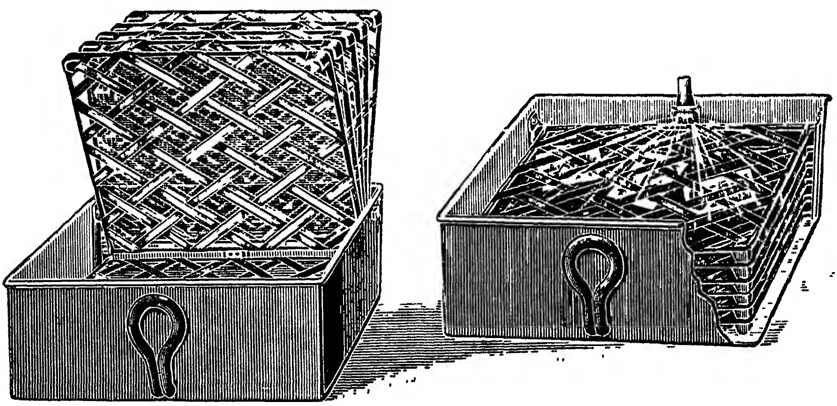


Fig. 139.—X-ray Print Washer.

the surface of the prints, it is well to employ some special arrangement for washing.

Fig. 139 illustrates an ingenious and useful print washer. A small tank is fitted with a series of frames latticed with linen tape, on which the prints are laid and kept from contact with each other, the trays being hinged a little distance apart. The supply pipe at the back of the tank is pierced with holes opposite each tray, and being connected by tubing to a tap, a stream of water is sprayed over each print. The water, with added salts (in solution or suspension) leaves the tank by a siphon which draws from the bottom of the tank, thus preventing deposition of salts. With such an arrangement half an hour ought to suffice for efficient washing.

After washing, prints should be allowed to dry by laying

them face upwards on a clean cloth or blotting-paper, in a place as free from dust as possible; they may be suspended from a line by means of clean wooden clips gripping the print at one corner, or pinned up on a clean board set vertically. The room should preferably be warm, but heat must on no account be employed to hasten drying. The remarks regarding drying of films, on page 198, apply also to prints.

It will be seen that this bromide process is specially suitable for the usual needs of a radiographer, although in itself more difficult to carry out successfully. The stronger contrast obtained in the picture is desirable, while the shorter time involved, and the possibility of making a print by artificial light, render the process at times very convenient.

The print while wet may be pressed by a rubber roller, or "squeegee," with its face against a sheet of glass to which it will adhere. In this position it may be safely handled for temporary examination, and it may, if desired, be fastened at its edges and allowed to dry gradually on this as a permanent mount.

Personal Precaution.—While working with developing or fixing solutions, unless the hands can be kept free from contact with them, as in working with films in hangers, the operator should wear rubber gloves or finger-stalls. Otherwise the chemicals will produce irritant effects on the skin around the bases of the finger nails, where probably there exists already a tendency to dermatitis from exposure to X-radiation.

The rubber-covered fingers may find some difficulty in picking up plates or prints from the tray of solution in which they are immersed, and for this purpose whalebone slips or other form of "lifters" are useful.

CHAPTER VI

STEREOSCOPIC VIEWS AND INTERPRETATION OF ORDINARY AND STEREOSCOPIC RADIOGRAMS

THE report on a radiogram should always, where possible, be made from the negative. This should be examined by transmitted light, the plate being placed between the eye and the source of light. To do this conveniently some form of lantern is advisable. A simple desk, with central area transparent like a photographer's retouching desk, may be employed where daylight is available; but daylight is very variable, and it is thus better to work with artificial light, which will always be available, and which, being of constant intensity, will allow comparison of negatives.

For this purpose a lantern is required with one flat and transparent face, on which the negative may be placed, while the other sides of the lantern are opaque, and reflect the light obtained from a suitable source inside the lantern.

Fig. 140 shews two such lanterns. The transparent face should be of "flashed opal" glass, which diffuses the light reaching the negative. This "flashed opal" is much more effective than the less transparent opal glass formerly employed. The back of one lantern is parabolic in shape, and reflects the light from an electric lamp supported at the focal point of the parabola; that of the other is in the form of a four-sided cone, thus furnishing four reflecting surfaces. The intensity of the electric light may be varied by means of resistance, an additional arrangement useful when viewing a very dense or a very thin negative. On the transparent face fit a series of frames, so as to accommodate any size of plate ordinarily used. A gas or oil light may be similarly fitted in a lantern, but, where available, electricity is certainly the best mode of illumination. Care must be taken not to leave a negative too long in contact with the window of such a lantern, especially if the negative be wet, or the heat may soften the film with disastrous results.

To examine a negative, place it with the film side outwards on the lantern. If the opaque frame does not fit closely round the edges of the plate, and a mechanical shutter is not fitted, lay strips of black paper or similar opaque material along these, so as to cut off all direct light from the eyes. Darkening the room will make the illumination of the negative much more efficient.

One end of a stereoscope, such as is seen in Fig. 143 or 144, may be employed for this purpose.

In the absence of a suitable glass front to diffuse direct light,

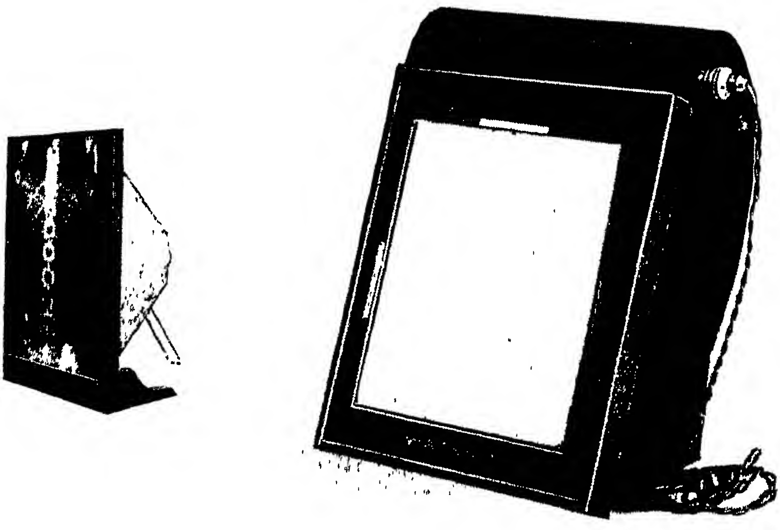


Fig. 140.—Negative Viewing Boxes.

a negative may be viewed against a surface painted matte white, which is arranged to reflect light from a concealed source. This is especially useful for large frames on which to view a number of plates.

Where it may be necessary to send plates to a hospital ward or operating theatre, especially while the films may be still wet and very easily damaged, it is an advantage to have a simple plate holder.

Those consist of metal frames of suitable size, fitted with sheets of opal glass and some arrangement for holding the plate in position.

The plate is placed with its film side towards the opal glass,

thus protecting the film from damage, but the film must not be allowed to dry whilst in contact with the glass.

The opal glass also serves to diffuse the light from any convenient source.

Celluloid films, single or double-coated, may be safely handled and sent for inspection in the metal frames used for development, etc. (see Fig. 141).

Densities of Shadow.—The first point to be remembered in reading a radiogram is that, as the name "negative" implies, the **plate** shews in density of shadow the reverse of the relative densities of the part exposed. Where dense tissue, such as adult bone, is interposed, much of the radiation is prevented

Fig. 141.—CARRYING FRAME OR HANGER FOR FILM.

from reaching the sensitive plate; hence little chemical alteration takes place in the corresponding parts of the plate, and the final result is a light transparent image of that tissue. Where, on the other hand, transradiant tissue such as muscle or, more markedly, air-filled organs, are interposed, much of the radiation reaches the sensitive plate, there is marked chemical alteration, and the result is a dense opaque image of that tissue.

Thus, clear transparent parts of the negative correspond to dense tissue, and dense opaque shadows to more transradiant parts. All grades of density, of course, appear and must be interpreted as meaning either normal differentiation or abnormal change. To diagnose the latter, an intimate knowledge of the form.r is essential. Even where such knowledge has been acquired by experience it is advisable, whenever there is

any reason whatever for uncertainty, that a radiogram of the corresponding part of the patient on the other side be made under exactly similar conditions for comparison. The advantage of this will soon be seen in practical work, and may be understood from its bearing on several points considered later in the section on diagnosis.

In a **print** everything is again reversed, so that dark shadows correspond to denser structures, and lighter parts to more transradiant tissue; hence such records are sometimes termed "positives." To the inexperienced, prints are thus easier to read than plates, though to the experienced radiographer they are of secondary value. The appearances on a print correspond to those seen on a fluorescent screen whilst exposed to radiation. (See Figs. 171 and 172, on page 250.)

Right and Left Side.—From the radiogram itself, without any information as to the conditions of exposure, it is always difficult, and may be impossible, to tell which side corresponds to the **right and left side** respectively of the part radiographed, unless there is some indicating mark on the plate.

If we are told on what aspect of the patient the **plate** was situated during exposure, we are able to settle the point, since the film side of the plate will always be turned towards the patient.

In such case hold the plate with its film side towards you, and imagine your eye to be in the position of the X-ray tube during exposure. Then the sides of the radiogram will correspond to the sides of the patient as he would appear from that position.

Thus, if the patient had his back to the tube and the plate in front of him, you must suppose yourself looking at his back, and the side of the radiogram to your right hand will correspond to the right side of the patient. On the contrary, if the patient had his face turned towards the tube and the plate set behind him, you must suppose yourself face to face with him, and the side of the radiogram towards your right hand will correspond to the patient's left.

On a **print** this relation is reversed, since the plate in printing is turned with its film side towards the paper, and away from the source of light. To realise the relations of a print is thus very confusing. A little consideration will, of course, define the relations of any radiogram if we know the conditions of its exposure, but it is better to obviate the

necessity by placing some indication on the plate during or after exposure.

Lead letters, R and L (either solid or cut out from a small disc), should be printed as a matter of routine on every plate or film.

With **duplitised films** this marking is absolutely essential, since it is impossible to indicate which of the two similar sides of the film was turned towards the patient.

Dimensions.—The dimensions of shadows as seen in a radiogram are not a true index, either absolutely or relatively, of the dimensions of the objects casting those shadows.

This point is discussed in other sections of the book. As there explained, all objects are magnified in a radiogram according to their distance from the sensitive plate, objects situated nearer to the plate being magnified to a less degree than those at a greater distance from it. This might be expressed by saying that a radiogram resembles a drawing in perspective, the eye being in the position of the X-ray tube.

By bearing in mind this fact, and applying his knowledge of anatomical dimensions, an observer may calculate from a radiogram the relative position of the parts depicted. Without such knowledge of actual dimensions, some idea may be gained of the relative distances of objects from the plate by noting the clearness of the outline of their images. An object near to the plate will cast a more clearly defined shadow as compared with that cast by a more distant object.

But this is a very indefinite indication, and would seldom, if ever, be relied upon for any practical purpose.

Thus it will be seen that a single radiogram gives a clear idea of the relative position of objects only in relation to the plane in which the plate was placed during exposure.

To obtain a visual conception of the true relative position of objects depicted by radiography it is necessary to take two views, which may be combined stereoscopically.

Stereoscopic Views.—Readers may be reminded that our conceptions of solidity, or of the relative position of objects in space, are obtained by the superposition of two visual images, one of which is perceived by each eye.

The principle of stereoscopic photography is to take two views of the same object from positions corresponding respectively to the right and left eye of an observer. By suitable means the observer is caused to receive simultaneous

impressions of these two views, one by each eye, so that the impressions may be superposed in his sensorium. By this means the combined views convey a sense of solidity and distance quite impossible to obtain from a single view.

In radiography the principle applies in the same way as in ordinary photography. Two plates are successively exposed in exactly the same position, but between the two exposures the X-ray tube is moved through a distance equivalent to that between the two eyes of an adult person, which distance may be taken as 6 cm. or, conveniently but inaccurately, as 3 in. The precise distance is not important, and a slight exaggeration, as in the latter figure, is often an advantage.

Various arrangements are in use to make these adjustments possible and convenient, but if the principle of the process be understood, all that is required is a convenient plate changing box and a means of measuring the movement of the tube. A plate changing box, like that illustrated in Fig. 128, will be found convenient, and if the cross wire frame shewn with it be left in position, its imprint on the plates may assist in alignment of the plates for later inspection. Wooden tunnels, as illustrated later in Fig. 146, are also very useful, being made to fit the various sizes of plate cassette in use. The tube shift is usually regulated by means of a scale set along the direction of traverse of the tube box, whether that be in an under table carriage (Fig. 111), or carried at the end of the horizontal stem of a tube stand (Fig. 104).

With the patient in position, the tube should be set exactly under the centre of the part to be radiographed, then for the first exposure moved into a position 1½ in. on one side of this central position.

A plate having been placed in the changing box and an exposure made, this plate must be removed and a second plate substituted. Now (or before setting the plate) the tube must be moved to a position 1½ in. in a direct line on the opposite side of its initial central position—that is, 3 in. from its position during the first exposure—and the second exposure made.

On most tables and tube stands an arrangement of stops or clamps is provided, so that when the tube has been set in its central position the two positions for stereoscopic exposures are automatically indicated and the tube shift controlled accordingly.

The detail of this mechanical arrangement is usually simple,

but differs in different designs of table or tube stand, so that it should always be inspected and thoroughly understood *before* proceeding to use any piece of apparatus for stereoscopic work. A similar tube shift is employed in most methods for localisation of foreign bodies, and is again referred to when that subject is discussed in a later chapter. Fig. 142 shews a simple arrangement fitted to the tube stand of the universal table described on page 141. B is one of two clamps fixing to the stem of the tube box a slender rod A, which moves through

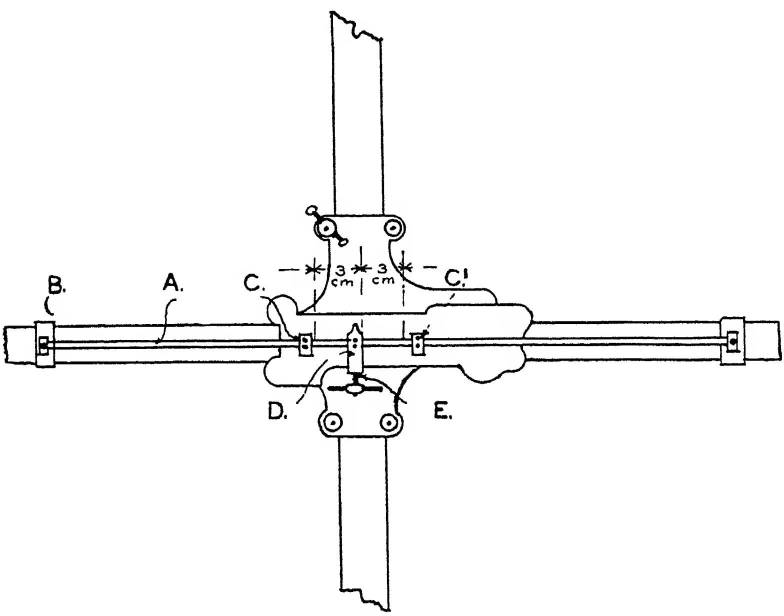


Fig. 142.—TUBE SHIFT CONTROL ON STEM OF TUBE BOX.

two small blocks, C C^1 fixed on the bracket carrying the tube box. D moves freely on the rod A, but can be clamped to it when desired by the screw E. Its movement between the blocks C and C^1 will then give the measured shift to the tube.

In order to **view stereoscopic radiograms,** it is usual for some suitable form of stereoscope to be used, though it is possible to combine two such views into one giving a sense of relief by the unaided vision. This requires some practice to accomplish satisfactorily, but it is well worth knowing and learning to do, for a stereoscope is not always at hand. The two radiograms should be set side by side, and the observer should set himself so as to have one opposite each eye. If he

hold up a finger between his eyes and the radiograms placed near to him, one to each side of his line of mid-vision, on looking at his finger his visual axes will cross, and he will see two views of each radiogram. By accommodative effort he may cause the two central images to be superposed, and, ignoring the two outside images, he will see one view showing the part radiographed in relief.

A similar effect is produced by standing about six feet away from the plates set side by side and holding at arm's length between the eyes and the plates a piece of cardboard, having in its centre a rectangular aperture about 2 in. by $1\frac{1}{2}$ in. The card must be adjusted till with the left eye closed, the right eye sees the left-hand picture framed by the aperture and the left

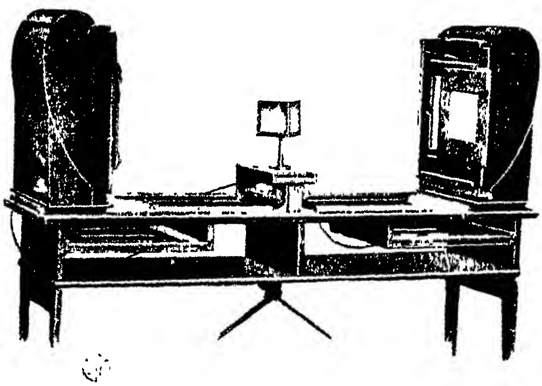


Fig. 143.—REFLECTING STEREOSCOPE.

eye similarly sees the right-hand picture. On opening both eyes and looking fixedly at the aperture the two pictures will coalesce.

A little practice secures this effect with ease, and it is worth a little trouble to acquire the art, which may prove very useful in the absence of suitable apparatus.

For routine work, however, some form of stereoscope will be used. That known by the name of Wheatstone serves well. As shown in Fig. 143, this consists of two viewing boxes at either end of a short baseboard, in the middle of which are two plane mirrors, arranged on a vertical support at the same height as the frames, and fixed with their backs forming an angle of 90°.

With a pair of radiograms in position, the observer places himself so that the space between his eyes is divided equally

by the vertical edge where the mirrors meet. With his face close to this edge, each eye will see the reflection in the mirror before it, and the two images thus seen will be merged into one perception of an image in relief.

Prints are easily viewed in this manner, and may be adjusted on the supporting frames by clips or pins.

The arrangment figured is adapted for plates, the viewing boxes permitting illumination, as described relative to Fig 140, and a dimming resistance being provided for each box, so that equal illumination is possible even if the densities of the two radiograms may differ.

Prints shew up very well in the stereoscope, but prints never shew the same detail or precision as the plates from

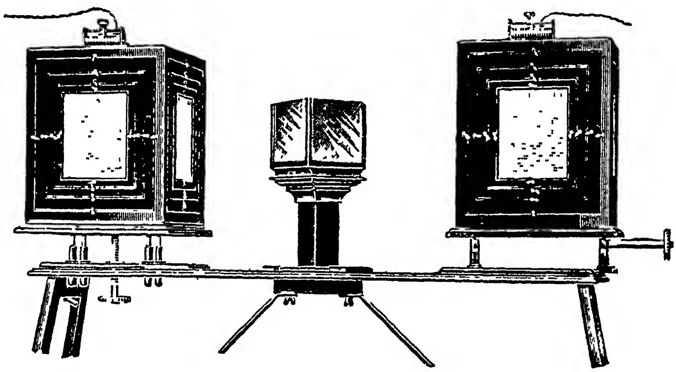


Fig. 144.—REFLECTING STEREOSCOPE,—MULTIPLE TYPE.

which they are made. The additional time necessary to make prints is a further drawback to their use in routine work, it being possible to view plates or films and make a diagnosis from them before they are dry, if necessary, or after only a preliminary washing of the fixed negative—washing being completed after inspection.

Films may be supported in the same manner as plates in the viewing box frames, or, as permitted by their lighter weight, they may be supported by one end in a large *spring clip* with universal movement.

The clip should be carried on a light bracket, fastened by a hinge to the base of the stereoscope, so that the film is held parallel to the front of the viewing box. This is especially useful for examining films whilst still wet, as mentioned above.

In a *multiple stereoscope*, such as is illustrated in Fig. 144,

urgent work is further facilitated by the possibility of examining several pairs of negatives without dismounting previous pairs, as when stereo-pairs have been made of a part in several aspects.

A method of combining four views on two plates is described in a succeeding section (page 218), which obviates the necessity of movement and permits inspection of stereoscopic views of two aspects of a part at the same time.

In both stereoscopes illustrated the central support carrying the mirrors is, as is usual, made with its base fitting into slides fastened on the baseboard tranversely; thus the alignment of the mirrors with the radiograms may be altered as desired. The frames or lanterns at either end are fitted so that they may be moved nearer or further from the mirrors, and in the more elaborate instruments there is further arrangement made for orienting the radiogram, so as to secure more accurate coincidence of the images. This mechanism is somewhat superfluous, though convenient, since it is found that the eyes by effort of accommodation can rectify considerable lack of alignment or coincidence. This will be readily understood when it is remembered that, as described earlier, two such views may be combined by the eyes unaided by any apparatus.

To obtain the correct relief of a part, the separate images must be received each by the appropriate eye, otherwise the relief will be reversed. By trial, in most cases, it will readily be seen whether the relief be correct; but for such purposes as location of a foreign body anatomical knowledge may not furnish such a guide, so it is important to understand how the radiograms should be set.

The operator must again imagine himself set with his eye in the position of the X-ray tube, and in this case it will be his right and left eye alternately, the tube travelling in a line at right angles to his visual axis. To prevent confusion, where the patient is lying down, the operator must always suppose his own head and feet to be in corresponding positions to those of the patient. Following this convention, each radiogram is named by the side—right or left—of the operator towards which the tube was situated during its exposure. By thus naming them with respect to the observer the same rule will apply to all radiograms, whether placed on the front or back of the patient.

If the radiograms be viewed direct, without intervention of

mirrors, they should be placed with the right-hand view to the observer's right, the film being turned in all cases towards the observer. If they be viewed in the reflecting stereoscope the positions must be reversed, since the reflection is the reverse of the original on the plate. With prints the rule is reversed in either case.

Pirie's Stereoscope, illustrated in Fig. 145, secures stereoscopic effect by introducing into the line of vision of one eye a double reflecting prism. This serves, at the proper distance, to superpose the image seen by that eye over that seen by the other through the plain tube of the instrument.

The negatives should be placed closely together on a suitable box or frame illuminated from behind by electric light or daylight, or they may be placed on a convenient window ledge.

Fig. 145.—PIRIE'S STEREOSCOPE.

For 12 in. by 10 in. negatives the observer should stand at a distance of about 3½ ft.

For smaller-sized negatives the observer should stand closer to the plates, for large negatives further away.

Small negatives or prints may be viewed in an ordinary **hand stereoscope,** this being very useful with radiograms of teeth.

Any subject may be viewed in such a stereoscope if a reduction be first made of each radiogram on a bromide paper of suitable size. This can be done while the original radiogram is still wet, and the reductions viewed immediately after developing, fixing and washing.

The use of the hand stereoscope, of course, dispenses with all special apparatus or illumination, and may be particularly valuable in localisation of foreign bodies, as described in Chapter VII.

The production of such reduced prints is briefly referred to in the chapter on Photography (see page 202).

Double Stereoscopic Views.

Two aspects of a part—such as antero-posterior and lateral views of a limb—may be represented stereoscopically on one pair of plates by suitable settings of the X-ray tube, one half of each plate being masked in succession by a piece of sheet lead.

For this purpose a series of wooden tunnels, to accommodate each size of plate cassette to be employed, is necessary, but those are simple and readily made, as may be seen from Fig. 146, and are useful for ordinary work where the plate is to be set under the patient. The top of each tunnel is marked

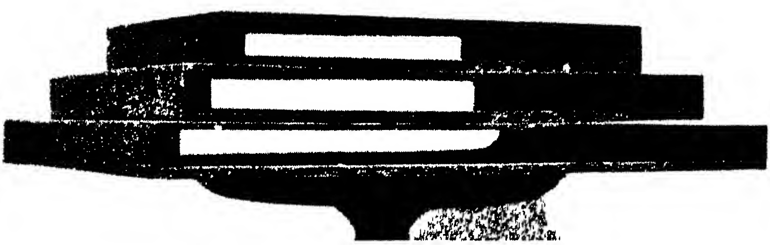


Fig. 146.—Plate Tunnels for Stereoscopic and Ordinary Radiograms.

into two equal halves, and each of those halves has its centre marked A and B respectively.

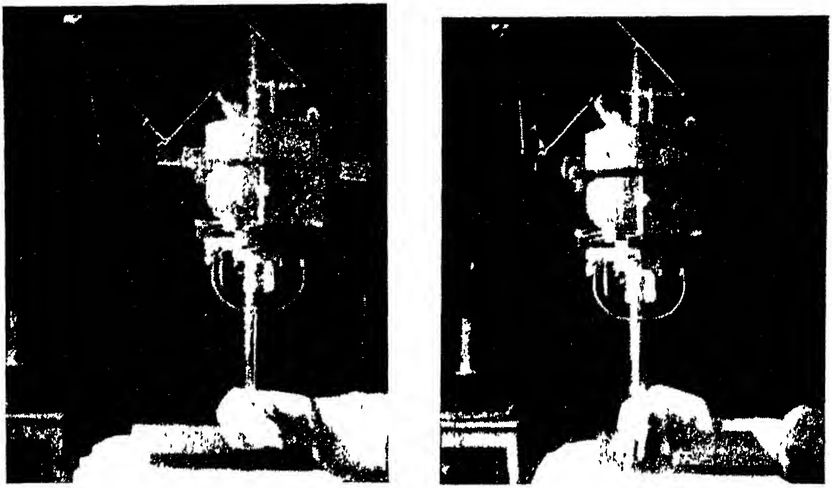
1st view.—With the tunnel lying horizontally the X-ray tube is centred over A, and the part to be radiographed is arranged over that half of the tunnel, whilst the other half is screened by a sheet of lead (see Fig. 147). A plate (I) in its cassette, which will occupy the whole tunnel, is introduced into the tunnel and an exposure made. A plate without cassette may similarly be used if slips of wood or an adaptor be introduced with it, so as to give it a definite fixed position in the tunnel.

2nd view.—Plate I is removed, a second plate (II) introduced, the tube moved through its stereoscopic shift, and a second exposure made of the first aspect of the part.

3rd view.—The tube is moved so as to be centred over B and the part is arranged in its second aspect over that half of the tunnel. The lead shield is moved to cover the A half of the

box, and a first exposure of the new aspect of the part is made —this being on the second half of plate II.

4th view.—Plate II is removed and plate I again introduced (with its unexposed half under B), the tube is moved through



1st View. 3rd View.

Fig. 147.—ARRANGEMENT FOR DOUBLE STEREOSCOPIC VIEWS.

its stereoscopic shift (back to its original position), and a second exposure made of the second aspect of the part.

Thus on plate I a view of the part in each of its aspects with the tube in the same stereoscopic position will be secured, whilst on plate II will be two corresponding views with the tube in its other stereoscopic position. By setting up I and II in a stereoscope, as already described, a combined stereoscopic view will be obtained of the part in its two aspects.

CHAPTER VII

LOCALISATION OF FOREIGN BODIES

Most foreign bodies which find their way into the tissues or organs are more dense than the surrounding tissues. Thus they may be detected by the relatively dense shadow cast on an X-ray screen or radiographic plate.

All metals and most varieties of glass (potash glass less than lead glass) cast an unmistakable shadow, though such substances as wood, leather, cloth, or paper are more difficult to demonstrate.

The localisation of foreign bodies, always an interesting and useful branch of radiology, assumes a tremendous importance during war time. **Bullets** and fragments of **other projectiles** are easily detected, and, in most cases, located for the surgeon; while pieces of **clothing**, equipment, etc., carried in with the missiles may be suspected from their blurring effect on superimposed outlines, although negative evidence regarding such relatively transradiant material may not be relied upon.

To ascertain the exact position of a foreign body, and note it for the guidance of a surgeon in its removal, various methods may be employed.

The method may be indicated by circumstances of the case, such as the nature of the part involved, possibility of moving the patient, or the time or apparatus available. The radiologist must remember, however, that his **work is necessarily and entirely accessory to the work of the surgeon**, and the method employed must be such as to give him the desired information in the manner or form for which he has a preference, even if it may seem to the radiologist less accurate than data presented in another form.

The surgeon is accustomed to work in relation to anatomical structures, and a **regional reference** may be **vastly more useful** to him than the most exact reference to depth and distance from points and planes more or less arbitrarily chosen. Such regional information will remain correct, however the patient may be moved or placed, so long as the foreign body itself does

not move in the tissues. Many suggested methods of localisation strive by mechanical means to produce mathematically accurate references, but are apt to ignore the psychology of the surgeon—one of the most important factors in the problem.

The principles underlying all methods of localisation are few and simple; the means of applying them should be kept as simple as possible; and the terms of reference to the surgeon should be plain and comprehensive and such as to be of the most practical assistance to him, even if some sacrifice be made of pseudo-scientific accuracy.

The actual procedures described by workers at various times are bewildering in number and, many of them, in intricacy. For a comprehensive description of various methods a perusal is recommended of the English translation of Ombredanne and Ledoux Lebard's "Localisation and Extraction of Projectiles," published as a War Manual.

The **method of choice** for precision and convenience is undoubtedly that known as the **triangulation method,** the application of which may be varied to suit the circumstances of the operator or to meet his personal preference.

A committee specially appointed by the War Office during the late war to report upon methods of localisation of foreign bodies, recommended that this should be the standard army method, and that it alone should be taught to X-ray attendants. They expressed the opinion that, in conjunction with the use of stereoscopic radiograms or plates taken in different directions, this method should suffice for the removal of foreign bodies in 90 per cent. of cases.

They further stipulated that radiograms in two planes should *never* be used as the *sole guide* for operation, except possibly in the case of foreign bodies embedded in bone, as in other cases it is entirely unreliable and very inaccurate.

To that may be added most emphatically that reliance should *never* be placed upon a *single radiogram* for localisation under any circumstances.

I.—**Screen Examination** by a simple method may prove a convenient and sufficiently accurate means of localisation in suitable cases, but in all screen methods the worker must specially remember to take special precautions for protection of his person (see page 158).

(*a*) If the part to be examined will permit, it may be viewed by the screen in two positions at right angles, and a cross

marked on the skin in each position in the line of the shadow. Then, where the perpendiculars from these points so marked may be supposed to intersect, the object will be found.

For this purpose the X-ray tube should be centred carefully, the diaphragm contracted, and the tube moved till the shadow of the object occupies exactly the centre of the luminous area. If the skin be marked on both aspects of the limb in each position the reference will be more simple, especially if the planes of observation be not accurately perpendicular to each other. A "ring localiser," as shewn in Fig. 148, may be used to aid in making the points where the "vertical ray" intersects the skin surfaces. This is slipped under the screen after the point of the foreign body selected for reference has been centred on the screen, and it is manipulated until the diagonal cross wires intersect over the selected point. The screen being removed while the localiser is held in position, the skin mark is made under the intersection of the cross wires. In the absence

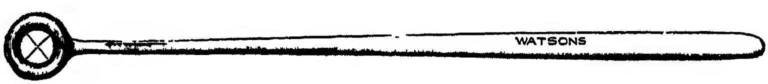


Fig. 148.—Ring Localiser.

of this accessory piece of apparatus, a probe set with its point to the selected point of the shadow, and held firmly while the screen is removed, may serve. Through such points intersecting lines should be drawn on the skin and prolonged beyond the possible area of operation, so that a reference may remain after the surgeon makes his incision.

This is chiefly applicable to limbs, but as a rough guide serves for many cases very well. A strip of lead tape may be moulded to the circumference of the limb, the points marked on it, and a cross-section of the limb so constructed from which depths may be measured.

The marks may be made on the skin by a special skin marker, by a pen with ink, or by a "skin pencil," either being guided by its shadow on the screen, but it is better to use silver nitrate or special skin marking ink, as otherwise the marks may be obliterated. A good formula for such ink is: acid pyrogallic, 1 gramme.; acetone, 10 c.c.; liq. ferr. perchlor. fort, 2 c.c.; spir. vin. meth. ad., 20 c.c.

The procedure of marking the skin in the line of the perpendicular ray is of importance, because it forms part of many

other methods of localisation; on page 238, in connection with one of those methods, a useful form of skin marker is illustrated and described.

(*b*) **Parallax Methods** depend upon observation of the degree

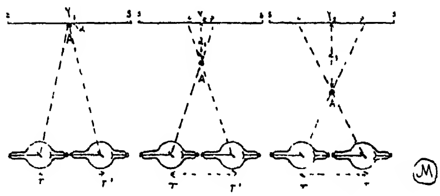


Fig. 149.—DIAGRAM OF SHADOW MOVEMENT.

S S, Fluorescent screen; A, small opaque object; T T', positions of X-ray tube at either end of travel parallel to S S; Y_1 Y_2 Y_3, path of shadow of A at distances d_1 d_2 d_3 from screen.

of movement of the shadow of the foreign body on the screen while the tube is changed in position.

Let a screen be fixed in position some distance above an X-ray tube, while the latter is moved in a plane parallel to the

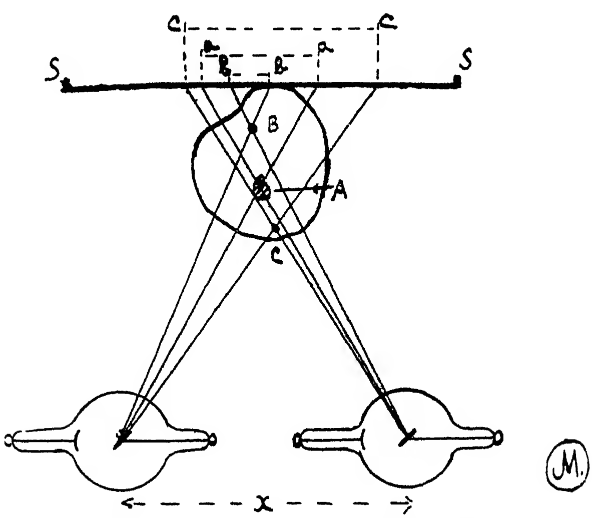


Fig. 150.—DIAGRAM OF SHADOW MOVEMENT.

S S, Screen; A, bone of limb; B C, foreign bodies in limb; X, travel of X-ray tube; a a, path of shadow of bone; b b, path of shadow of B; c c, path of shadow of C.

screen; and let a small opaque object be interposed so as to cast a shadow on the screen. If that object be close against the screen, it will be readily understood that the shadow cast will not perceptibly change position on the screen as the tube is moved. But if the object be some distance below the screen,

the shadow will be seen to change position as the tube is moved; and as the object recedes from the screen towards the tube, the path traced by its shadow will gradually lengthen for the same travel of the tube.

A glance at the accompanying diagrams (Fig. 149) will explain this more clearly than words.

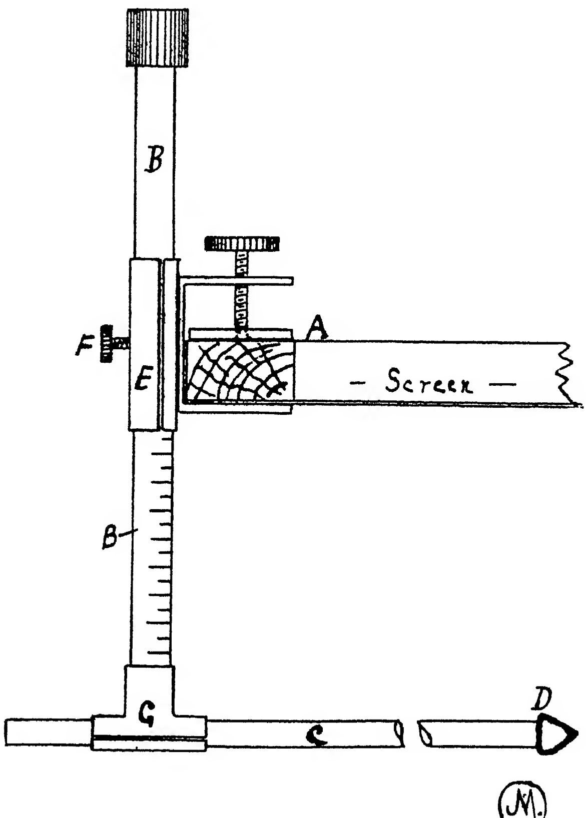


Fig. 151.—SHENTON'S LOCALISER.

If the part examined has bone in it, then by noting the relative paths of the shadow of the bone and of the object, we may tell directly whether the object is on the side of the bone proximal or distal to the screen. This may be valuable knowledge, but in most cases is too indefinite to guide exploratory operation, and further information is required by the surgeon. Fig. 150 illustrates the conditions referred to.

Shenton's localiser takes advantage of the fact illustrated above, and by a simple mechanism reduces it to exact terms.

It consists of a simple piece of apparatus, whereby an opaque test object may be temporarily fixed at any distance from a screen, so as to be interposed between that and an X-ray tube which illuminates the screen from below.

It is shewn in accompanying figure fixed to the frame of a fluorescent screen at A (see Fig. 151).

In the fixed part the rod (B) can be moved vertically, carrying with it the horizontal arm (C), which is tipped by a pointed mass of lead (D). The rod (B) is gripped by the sleeve (E) somewhat tightly, so as to prevent it slipping down by its own weight, and may be further fixed by the screw (F).

The rod (C) can likewise be moved in the sleeve (G).

Along B is marked a scale of inches or centimetres, from which the vertical distance of D from the screen may be read, or this distance may be measured directly.

In use, the fluorescent screen should be placed in a horizontal position, in contact with the upper surface of the part to be examined. A shadow of the foreign body being seen, the X-ray tube must be adjusted so that the shadow occupies the centre of the area illuminated through a contracted diaphragm. The position is marked on the skin, as described in an earlier method, by a cross, and the localiser is then brought into use. Set the horizontal arm (C) and the test object (D) fairly near the screen, and move the tube slowly in any horizontal direction. If the foreign body sought be at some distance from the screen, the increased range of movement of its shadow, as compared with that of the test object, will readily be noted. If the two objects be more nearly in the same horizontal plane, the difference will naturally be less. Adjust the height of D until, by repeated trial, a position is reached in which its shadow has a travel exactly equal to that of the object sought; the two objects will now be at equal distances from the screen.

If the distance of D from the screen be then ascertained by reading the scale on B or by actual measurement, the surgeon may be told that "vertically under the point marked on the skin, and at that measured depth from the surface, he will find the object sought."

A modification of this localiser, designed by Jordan, has two pointers, so that, where possible, one is set on each side of the limb and both are adjusted as described above. This checks the accuracy of the observation and may also prove the

horizontal position, or otherwise, of the screen. Each point may be set on the skin after adjustment and marks made, thus giving the advantage of method (*a*) in addition to the measurement of vertical depth.

Fig. 152.—Stereoscopic Views for Localisation.

II.—**Stereoscopic views** may be taken, and serve excellently. Many surgeons prefer this method, as it shows the correct anatomical relations of the body in a way easily comprehended. For description of the method of making stereoscopic radio-

grams, see Chapter VI, at p. 211. An irregular piece of metal wire or other opaque indicator should be laid upon the skin surface on which the plates are laid, so as to indicate the level of the skin. For this purpose the process described for reduction of radiograms so that they may be viewed in a hand stereoscope, is particularly useful. The surgeon can then have a record beside him while he operates, and can readily refresh his impression if necessary (see Fig. 152).

Whilst this may, in certain cases, be all that is required by the surgeon, the radiologist should always prepare definite data of situation and depth, so that those may be available if required in addition to the stereoscopic localisation.

III.—**Triangulation Methods** may be based either upon screen examination or upon exposure of plates, and are applied to define the position, and measure the depth, of a foreign body from the screen or plate by observation and measurement of the movement of its shadow, while the tube, at a fixed or known distance, is moved through a fixed or known path.

The details of the various methods dependent upon triangulation differ considerably, but all depend upon the same principle, and, understanding that, the worker may choose the form of application of it and the method of interpreting the data so obtained. Here again the tube must be carefully centred (as described on page 135), so that with the diaphragm contracted to its smallest the emerging ray is vertical in its direction. As before, the foreign body will thus be known to be vertically under, or over, its shadow on the screen or plate.

Fig. 153 illustrates the method, the movement of the tube and the distance between the screen and the antikathode of the tube being fixed at convenient figures for ordinary conditions and for ease of calculation.

It is not essential to have those distances fixed or constant for all observations, but it adds much to the convenience of the method.

In exact localisation of a foreign body it is helpful to consider the process as in two essential steps, and to define the indications likewise, although in practice the two steps may be more or less combined. Thus considered, a complete localisation consists of (*a*) *indication of the position* of the foreign body relative to *anatomical markings* or to *skin markings* considered as projected on the same horizontal plane; and (*b*) *estimation of the depth* of the foreign body from the skin surface, this being

reckoned as vertical, whilst the part under survey is in a position which may be conveniently and accurately reproduced on the surgeon's operating table.

(*a*) **Indication of Position (horizontal) of Foreign Body.**—Where circumstances permit of marking the skin vertically over the ascertained position of the foreign body, as described on page 222, the first step is easily accomplished; but, where circumstances of the patient or of available apparatus render this process impossible, recourse must be had to a less direct method of indication. To make screen observations, it is

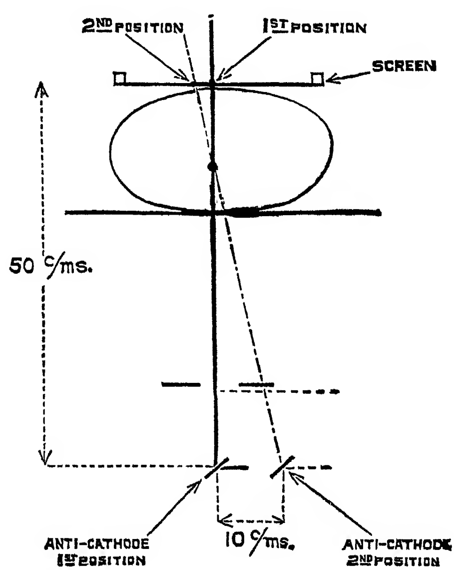


Fig. 153.—Diagram of Triangulation Method of Localisation.

necessary to have the X-ray tube under the patient or to one side, but the use of plates is equally possible with the tube above the patient, and in many cases this will be the position of preference. To obtain the required data by this more general method it is required to expose *two plates* in succession in the same position, or to make two exposures of one plate, the X-ray tube being shifted through a known distance between the successive exposures, as in making a stereoscopic pair. In order to ensure a convenient record on the plates it is essential, or at least very helpful, to make a *preliminary screening* of the part so as to ascertain approximately the position of the foreign body; or, if that be impossible, a "*spot plate*" should be exposed

after having placed on the skin a "known body"—such as a lead arrow—and made on the skin a mark of its position. From the information thus obtained, the plate holder may be placed so as to receive the desired record, and the X-ray tube may be centred vertically over the foreign body.

A *plate holder with cross wires*, as illustrated on page 179, is essential; and, unless anatomical relations are likely to be plainly recorded on the radiogram, a "known body" should be placed so as to be recorded in one quadrant of the plate.

The *position* of the cross wires and of the known body should be *marked on the skin*, the wires being inked in readiness before being placed in contact with the patient. The *distance of the target* of the X-ray tube from the sensitive plate should be noted, and it is advisable, especially for the later calculation of depth, to fix this at a convenient figure, such as 50 cm. (approx. 20 in). The *movement of the tube* between the two exposures should be parallel to one of the cross wires of the plate holder, and the shift should be of measured length—conveniently 6 cm. (2·4 in.).

As in stereoscopic exposures, the two positions of the X-ray tube should be at equal distances on either side of the position already selected as vertically over the site of the foreign body.

In each impression made by the two exposures, the position of the cross wires shadow and the known body shadow will be unchanged, since those were close to the plate; but the two shadows of the foreign body will shew a shift in position in proportion to the distance of that body from the plane of the plate (see Fig. 150, on page 223).

The relative position of its shadow to that of the known body will indicate the position of the foreign body in the quadrants formed by the cross wires and marked on the patient's skin; it remains to measure the exact horizontal distances of the foreign body from the vertical planes of the adjacent cross wires. This may be measured (i) by means of apparatus which reproduces by *pointers and threads* the relative positions of tube, plate, and foreign body during exposure, or (ii) it may be ascertained *graphically* by plotting on paper the data recorded on the plates.

(i) **Mackenzie Davidson's Cross-thread Localiser** is the classical piece of apparatus designed to reproduce the relative positions referred to, and this also serves to measure the depth of the foreign body. With an X-ray tube and screen fixed in position relative to an interposed object, it is evident that a

straight line passing from the focal point of the tube to any point of the shadow cast on the screen must pass through the corresponding point of the object, as shewn in one plane in Fig. 154.

Then, as shewn, if the tube be moved into another position, while the object remains stationary, the same will hold true, and another line be obtained, which must pass through the same point of the object. Thus the intersection of those two lines will determine the position of the point in question.

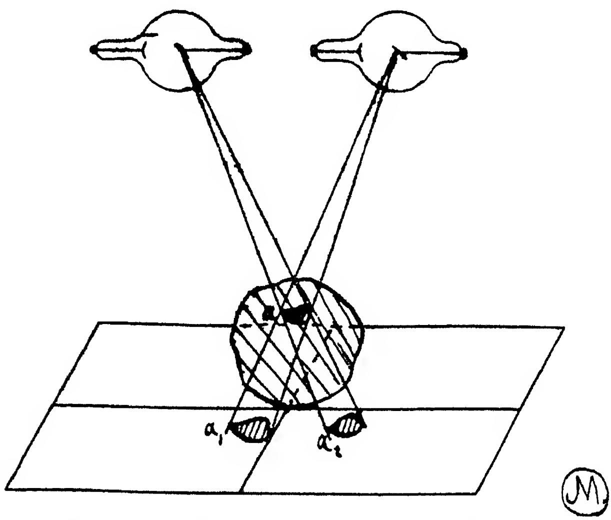


Fig. 154.—DIAGRAM OF LOCALISING SHADOWS.

This, applied to foreign bodies in the tissues, is the principle of the localising method first described by Mackenzie Davidson.

Fig. 155 shews a recent form of the **cross-thread localiser** employed to interpret the recorded data.

On the horizontal surface of the base are marked two lines crossing at right angles, which correspond to the cross wires imprinted on the plates exposed. The upright is engraved with a scale in inches and centimetres, so that the horizontal arm may be set to the distance noted of the tube above the plate during exposure. The horizontal arm carries a **T**-piece marked by a notch at its centre and also at points 3 cm. and 6 cm. on each side of its centre, so as to reproduce positions of the X-ray tube.

If one plate has been exposed, it is laid film upwards on the base, and set so that the image of the cross wires corresponds exactly to the lines on the surface. If two plates have been exposed, these may be superposed on the localiser so that the images of the cross wires coincide with each other and with the lines on the base, but it will usually be preferable to trace each in succession on one sheet of celluloid. That should

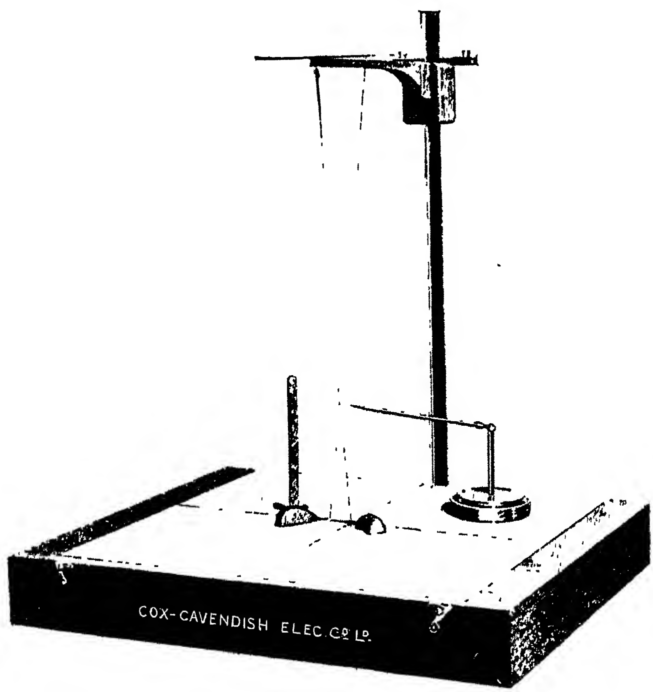


Fig. 155.—CROSS-THREAD LOCALISER.

be similarly set on each plate while the tracing is made, and then it should be placed in position on the localiser. A single plate may be similarly traced if its record is indefinite.

A thread is now passed, as shewn in the figure, over the T-piece at each point representing the antikathode, and one thread is led to each of two small pointers attached to weights with flat bases ("mice"), which rest on the surface of the plate or celluloid. (To the other end of each thread is usually attached a small weight, which keeps it taut.) The flat weights

are placed so that the threads cross, as shewn, and the pointer of each is set to a corresponding point of each shadow of the foreign body.

These threads now represent rays passing from the anti-kathode of the tube in its two positions; and, were the patient in position, each of these would pass through the same point of the foreign body. Thus the point of crossing of the threads (which should just touch each other) indicates the position occupied in the exposure by that point of the foreign body which corresponds to the points indicated in the shadows.

The perpendicular distance of the crossing of the threads from the plane surface will indicate the depth of the foreign body from that surface of the part which was in contact with the plate during exposure; and, by setting up a perpendicular

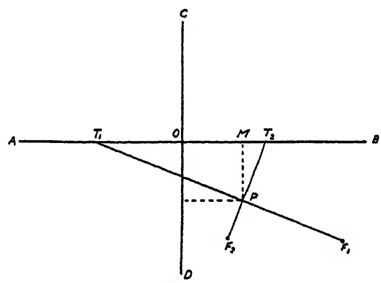


Fig. 156.

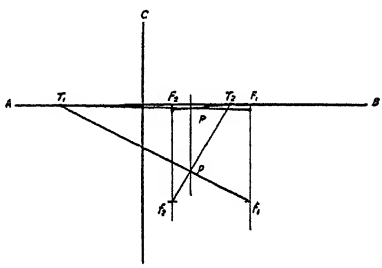


Fig. 157.

DIAGRAMS TO LOCATE POSITION OF FOREIGN BODY RELATIVE TO CROSS WIRES.

from each of the cross lines in turn, the horizontal distance of the point from each may be measured.

This method by use of cross threads is irrefutable in principle and most educative in practice, but it is somewhat tedious and the precise measurements are sometimes not so simple to make as to describe. Unless for demonstration purposes, therefore, the method is seldom employed in its entirety.

(ii) From data similar to those detailed for the above method, the horizontal position of the foreign body may be ascertained by *graphic diagram*, whilst the depth is calculated by a simple formula explained in a later section.

Two exposures having been made as above described, the exact horizontal distance of the foreign body from the vertical planes of the cross wires may be calculated as follows:—

Draw two straight lines AOB and COD at right angles, as in Fig. 156, to represent the cross wires, AB being that parallel to which the tube has been shifted.

F_1 and F_2 are the two positions of the shadow of the foreign body obtained from the plate or plates exposed. Mark off the points T_1 and T_2 3 cm. (or other distance) on either side of O to represent the two positions of the tube. Join T_1 to F_1 and T_2 to F_2. The point of intersection of T_1 F_1 and T_2 F_2 is the *point upon the plate vertically below or above which the foreign body lies.* Measure off OM and MP to obtain the distances of this point from the cross wires CD and AB respectively.

Should the shadows of the foreign body F_1 and F_2 fall upon the shadow of the cross wire AB, or so close to it as to make indistinct the point of crossing of the lines T_1 F_1 and F_1 F_2, proceed as follows (Fig. 157):—

(*a*) Through F_1 and F_2 draw lines parallel to CD.

(*b*) On those lines mark two points f_1 and f_2 at convenient points equidistant from AB.

(*c*) Join T_1 to f_1 and T_2 to f_2, crossing at p.

(*d*) Through p draw a line parallel to CD.

The point P denoting position of the foreign body must lie somewhere on that line, and the original lines T_1 F_1 and T_2 F_2 will denote the exact point on that line.

The above estimation assumes that the antikathode of the tube has been centred vertically opposite the wire crossing, that the foreign body is opposite a definite quadrant of the included area, and that the positions of the tube during exposure were at equal distances on either side of the central positions. Other definite positions of the tube may be chosen, so long as they are noted for reproduction in the figure; such as one position vertically over the wire crossing and the other a definite distance to one side of the vertical, this latter setting being often more convenient.

(b) **Estimation of Depth of Foreign Body.**—The estimation of depth by the Mackenzie Davidson cross-thread localiser has already been referred to in the preceding section. Other arrangements of threads and scales are in use and also graphic methods, such as reproduction in full size or to scale (as in Fig. 159) of the data shewn in Fig. 153, but the alternative method of *calculation by formula* is more convenient and much more commonly employed.

Towards this calculation it is necessary to know:—

(i) Distance of antikathode of tube from screen or plate.
(ii) Shift of X-ray tube between two positions of exposure.
(iii) Corresponding shift of shadow of the foreign body.

(i) and (ii) may be measured for any individual calculation,

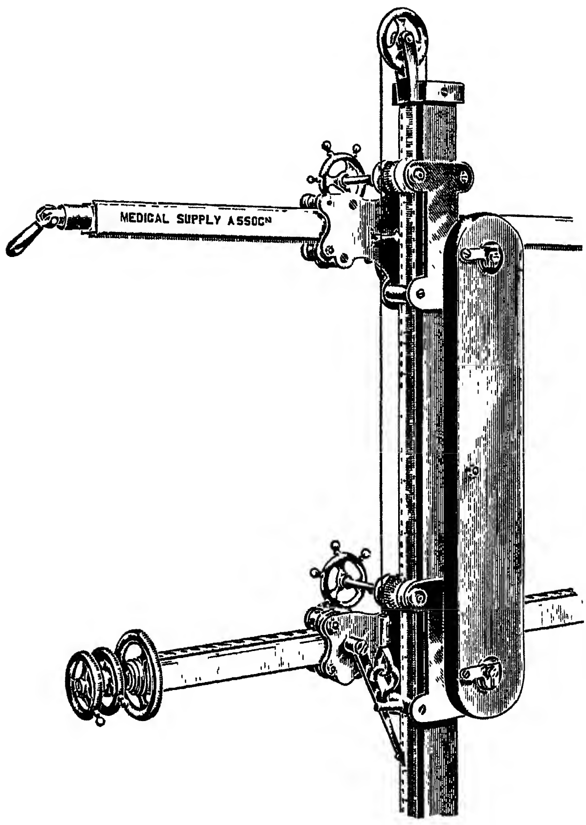


Fig. 158.—Link to fix Distance from Tube of Screen or Plate.

or may be arranged as constant quantities for a series of observations.

(i) Most tube stands have a vertical scale attached to their upright stem (as in Fig. 158), by which (i) may be readily set or measured, or the actual distance from tube to plate may be fixed by direct measurement before the patient is placed in position. To fit on the universal table, described on page 141, a

link, shewn in Fig. 158, is provided to fit between the brackets carrying the tube box and screen carrier respectively, so as to maintain the tube target and the screen or plate at a fixed distance of 50 cm., but such an arrangement is for convenience only and is not essential to the method.

(ii) The "*tube shift*" may have to be measured on a scale fixed along the horizontal traverse of the tube box, as shewn in Fig. 158, but on most tube stands and tables there is special provision made of mechanical stops or clamps to regulate the tube shift appropriate for taking stereoscopic views, and this same arrangement serves well for purposes of localisation. One such arrangement is shewn in Fig. 142, on page 213.

(iii) The "*shadow shift*" may be measured on a fluorescent screen (as described later), from one plate exposed with the tube in each of its two positions, thus bearing two shadow impressions of the foreign body, or from two plates exposed in succession, each bearing one shadow of the foreign body, and each bearing a record of the cross wires whereby they may be set in alignment.

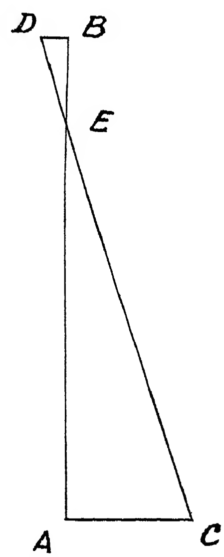


Fig. 159.—TRIANGULATION.

The latter method, by two plates exposed in succession, is the better, since the plates can be viewed as a stereoscopic pair, in addition to furnishing data for the calculation.

To obtain the shift of the shadow of the foreign body, lay a piece of tracing paper or celluloid over Plate No. 1, and mark carefully the positions of the cross wires, also the position of a recognisable point of the foreign body shadow. Transfer to Plate No. 2, and see that markings of cross wires coincide with the shadows of the cross wires obtained upon this plate. Mark the second position of the same point of foreign body shadow. By means of dividers and scale read off the shift of the foreign body shadow.

In Fig. 153, on page 228, the relative positions of tube, foreign body and screen are diagramatically shewn, and in Fig. 159 those are reduced to a mathematical figure, in which AB represents the vertical distance from antikathode to screen or plate, AC the travel of tube, and BD the consequent

movement of the shadow cast by a foreign body situated at E. Then from similar triangles :—

$$BE : AE : : BD : AC \text{ and call } BE = X.$$

$$\therefore X = \frac{BD \times AE}{AC} = \frac{BD}{AC} \times (AB - X)$$

$$\therefore X \times AC = BD \times AB - X \times BD.$$

$$\therefore X (BD + AC) = BD \times AB.$$

$$\therefore X = \frac{BD \times AB}{BD + AC}$$

that is :—

$$\text{Depth of foreign body} = \frac{\text{Shadow shift} \times \text{Tube distance}}{\text{Shadow shift} + \text{Tube shift.}}$$

This formula will apply to any set of conditions, and with AB and AC fixed at convenient figures the calculation is certainly simple enough. The movement of the shadow (BD) must be measured very carefully, as the accuracy of the method depends almost entirely on that measurement. For any values of the tube distance and tube shift (AB and AC) reckoned as constants scales may easily be constructed, and reference to such will obviate repeated calculation.

For a fixed distance of 50 cm. and a tube shift of 6 cm., the annexed table gives in centimetres the depth of a foreign body for any shadow shift from 1 to 30 mm. :—

LOCALISATION TABLE.

Distance, 50 cm. (approx. 20 in.). Tube Shift, 6 cm. (2·4 in.).

Shadow shift in mm.	Depth of F.B. in cm.	Shadow shift in mm.	Depth of F.B. in cm.
1	0·8	16	10·5
2	1·6	17	11·0
3	2·4	18	11·5
4	3·1	19	12·0
5	3·8	20	12·5
6	4·5	21	13·0
7	5·2	22	13·4
8	5·9	23	13·8
9	6·5	24	14·3
10	7·1	25	14·7
11	7·7	26	15·1
12	8·3	27	15·5
13	8·9	28	15·9
14	9·5	29	16·3
15	10·0	30	16·7

Note.—Always work in common units: approximately 2·5 cm. = 1 in.

The calculation may be rapidly performed—after a little experience—by use of a *slide rule* specially adapted for the conditions of the problem.

Such a localising slide rule was devised by F. J. Harlow for use during the late war. It is shewn in Fig. 160, and is arranged for quickly and accurately multiplying and dividing the particular numbers met with in localisation.

The detail of its use need not be set out here, as full instructions always accompany each slide rule.

Conversion scales have been constructed with pointers attached, so that the depth may be read directly by setting the pointers to successive positions of a definite point of the foreign body shadow produced on a screen by a tube in two defined positions, and at a fixed distance from the screen.

In operation, each indicator should be moved always from an illuminated area up to the border of the foreign body shadow to

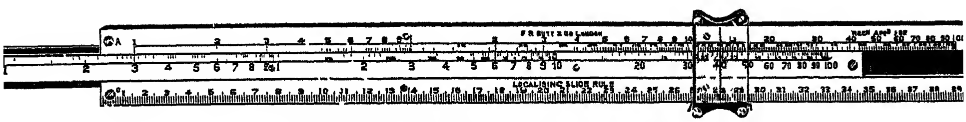


Fig. 160.—LOCALISING SLIDE RULE.

touch it without overlapping. The conversion scale, calculated for the pre-arranged tube distance and tube shift, in the usual design moves with one indicator limb; and, when both limbs have been set, the inner edge of the second will mark on the overlying scale the figure corresponding to the estimated depth of the foreign body from the screen.

In all cases the **measurement obtained** by this triangular method of localisation, as also by the parallax method, indicates the **depth** of the foreign body **from the screen.**

If that be not in close apposition to the surface of the part under examination, the distance between screen and skin must be deducted from the figure obtained.

Where a screen is used, or where the plate is carried above the patient, it is convenient to measure this intervening space by means of a small hole in the screen or plate carrier, through which a measuring rod may be passed.

Such a rod, combined with a direct skin marker, is illustrated in Fig. 161, which is self-explanatory.

To make apposition of the screen more easy, Dr. Thurstan

Holland uses a small screen, 6 in. by 2 in., covered by lead glass and mounted in a frame of protective rubber.

A small hole is drilled through the screen and glass, and this is manœuvred over that point of the first shadow which is to be observed, so that the skin may be marked directly through the hole. On one side of the screen is a scale, on which slides a pointer, whereby the movement of the shadow may be measured. By reference to charts constructed for different distances of antikathode to screen, the depth of the foreign body from the screen may be read off for any reading of the scale.

IV. **Operation by Direct Observation.**—In all screen methods it is essential for the surgeon's guidance that the limb be placed on the operating table in exactly the same position as that in which the measurements were made, and this is not always easy. Distortion of the parts may occur during the

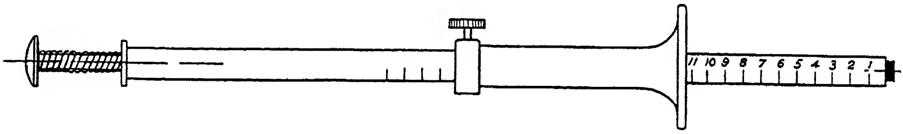


Fig. 161.—Combined Skin Marker and Vertical Scale.

operation, and the indicating marks and measurements are thus apt to lose their value.

It is suggested, to avoid those difficulties, that the X-ray table should be the operating table, that the surgeon should be present at every localisation, and that the radiologist should assist at the subsequent operation for removal of the foreign body. The surgeon would thus be guided in his operation by periodic observation on the screen as required, and as interpreted by the radiologist.

The method was carried to a high pitch of efficiency by some of our French *confrères* in the late war, and it is fully described in Ombredanne and Ledoux Lebard's book already referred to (page 221); but the procedure has never found favour with British surgeons, and, except possibly for a few cases of especial difficulty, it is not likely to become common practice.

V. **Special Methods.**—(*a*) The "*Grid Localiser*" is a simple piece of apparatus for estimation of the depth of a foreign body, the principle of which might be said to be a variant of

"triangulation." The method was employed to a considerable extent in the late war, and was described in detail in the *R.A.M.C. Journal* for January, 1919.

Principle of Method.—The principle is illustrated in Fig. 162, and should be understood from the attached descriptive note.

T_1 and T_2 are two successive positions of the target of the X-ray tube, producing shadows S_1 and S_2 of the foreign body F. A and B are opaque bars on a transradiant plate on the tube box opening.

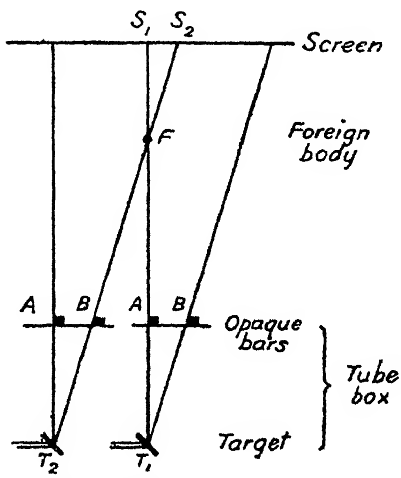


Fig. 162.—PRINCIPLE OF GRID LOCALISER.

The triangles T A B and F S_1 S_2 are similar in all respects, therefore—

$$\frac{F\ S_1}{S_1\ S_2} = \frac{T\ A}{A\ B}$$

If A B be made $\frac{1}{4}$ T A, then S_1 S_2 will be $\frac{1}{4}$ F S_1, or conversely F $S_1 = S_1\ S_2 \times 4$, *i.e.*, depth of foreign body = shadow shift × 4.

Application.—In all tube boxes it should be possible to set the central focus spot of an enclosed tube to the level of the viewing hole in the tube box (see page 136), and the distance of that level from the front of the tube box may be measured. On the tube box front, across its opening, should be fitted a thin sheet of aluminium carrying opaque bars set with their centres at a distance equal to a convenient multiple of the distance from viewing hole to front of tube box.

The tube box opening is usually of width more than one-half

of the above distance, so that the total width of the localising "grid" may be arranged to be one-half of its distance above the tube centre. This will give a ratio of one-fourth on either side of the centre; and three indicating slots or bars may be fitted, one central and two lateral.

This is represented in diagram in Fig. 163.

With a restricted tube shift, as when the shift can only be made transverse to the table, and with a foreign body near the surface of the part under examination, or situated at some distance to one side of the centre of the width of the table, the two settings will be made to the central bar and one of the lateral bars, and the multiplier to convert measurement of

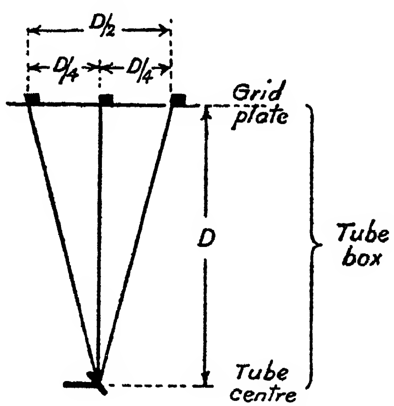


Fig. 163.—Diagram of Localising Grid on Tube Box.

shadow shift into foreign body depth will be four. This is shewn in Fig. 164.

With a convenient longitudinal traverse of the tube box, or with a well designed transverse movement and a foreign body situated near the centre of the width of the table, the settings may be made to the two lateral bars, and the multiplier in that case will be two.

This is shewn in Fig. 165.

The simplicity and rapidity of this method will be obvious when it is realised that no preliminary measurement or setting is called for, as the only factor required is fixed once and for all in fitting the grid plate to the particular tube box in use. The screen may be at any distance from the tube as found most convenient; nor need the tube shift be noted or measured, that being controlled by the setting of the foreign body shadow

to its two positions. The traverse of the shadow between those two positions alone requires measurement, and that proceeding is a familiar one to all workers, whilst the after calculation is extremely simple.

(*b*) **Shenton's Plate Method.**—It is impossible even to mention all the various methods and modifications proposed for localisation, and it should be recognised that the efficiency of any method in the hands of an individual may depend very largely upon his familiarity with that particular method, so that

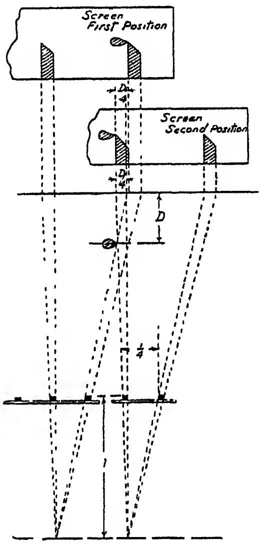


Fig. 164.—GRID LOCALISER AND SCREEN APPEARANCE.—SETTING TO CENTRAL AND LATERAL BAR SHADOW.

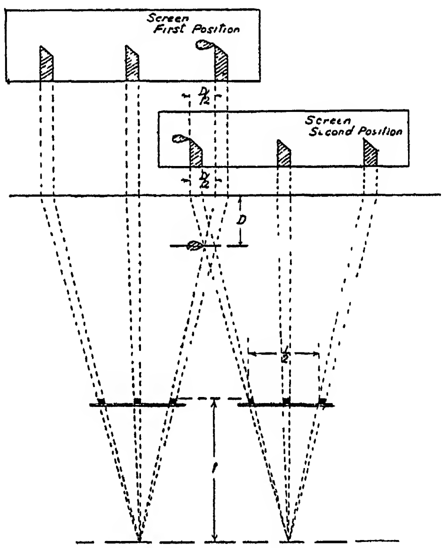


Fig. 165.—GRID LOCALISER AND SCREEN APPEARANCE.—SETTING TO TWO LATERAL BAR SHADOWS.

comparison of results is not easy. Another method employing plates and depending upon principles of "triangulation" is here mentioned on account of its great simplicity, although its use has not been very widespread.

Two plates are here set above the part, parallel to each other, with films downwards, and with a fixed measured distance between them. When an exposure is made, a record of the foreign body will be produced on each of those plates. The relations are shewn diagramatically in Fig. 166, a a^1 and b b^1 being on the lower and upper plates respectively, whilst the X-ray tube is at T and the foreign body at fb.

After a first exposure, the tube is moved through a convenient but unmeasured distance and a second exposure is made on the same plates.

The plates are then developed, the distance between the two records of the foreign body on each plate is measured (*a a*[1] and *b b*[1]), and those positions are reproduced on a chart, as at A A[1], B B[1], in Fig. 166, or on scales set at the same distance apart as the plates were placed during exposure.

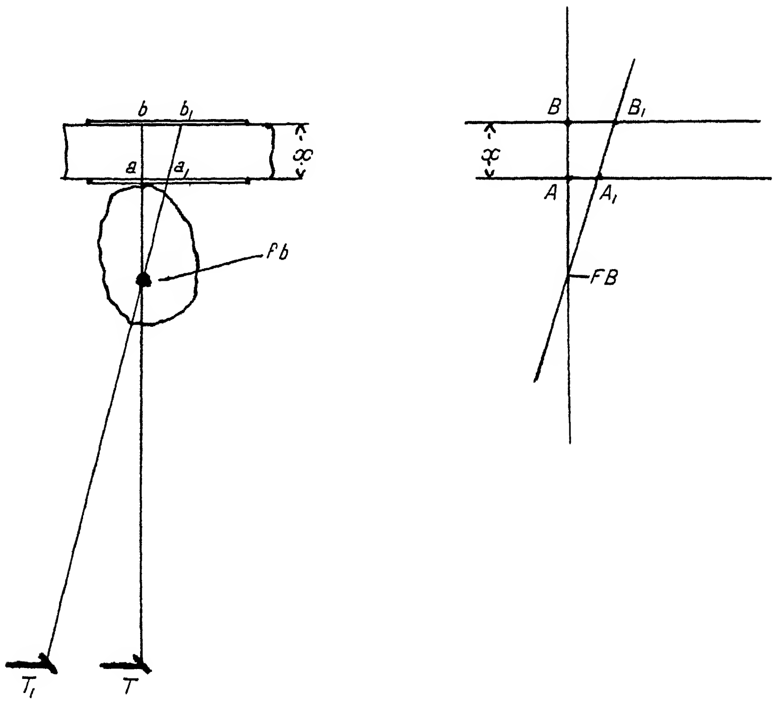


Fig. 166.—THE TWO-PLATE METHOD OF LOCALISATION.

By joining up the corresponding records, B A and B[1] A[1], and producing the lines till they cross, the position of the foreign body is reproduced (as at F B), and its perpendicular depth from the bottom plate may be measured (A to F B).

As the tube will probably be set vertically under the foreign body for the purpose of marking its position, as described on page 222, it will be convenient to make the first exposure in that position, but the precise position of the tube in that respect does not affect the accuracy of the result.

The length of shift of the tube need not be measured, and

is limited only by the necessity of keeping the image of the foreign body within the borders of the upper plate. The only distance requiring measurement in the exposure is that between the two plates, and that may be fixed at a convenient figure, say 5 or 10 cm. for all operations.

Foreign Bodies in the Eye.—This is a most important localisation, much depending on the diagnosis as to whether the foreign body be in the eyeball, or external to it. Many different methods applicable to this region have been suggested, and several are in use which differ considerably in principle and detail of the apparatus employed. The apparatus illustrated in Fig. 167 is a modification, due to Mr. Mayou, of Mackenzie Davidson's localiser.

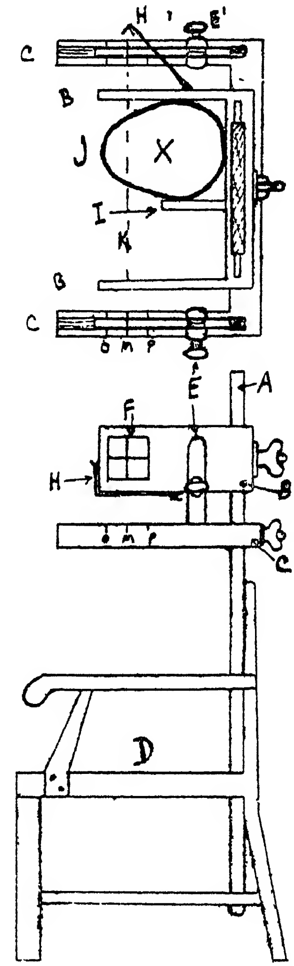


Fig. 167. — Mr. Mayou's Modification of Mackenzie Davidson's Localiser for Foreign Bodies in the Eye (Royal London Ophthalmic Hospital). (The frame marked C should be much broader than is shewn in figure.)

A is a broad, solid piece of wood, extending upwards from the back of the chair D, to which it is securely bound.

B is a three-sided rectangular frame of wood sliding vertically upon the upright A, and can be fixed in position by a thumb-screw. Near each free end there is an opening large enough to hold a quarter plate with envelopes, and into this opening fits a light wooden frame, across which are stretched two fine cross wires.

C is a similar shaped frame of wood, wider between its arms than B, supporting on each arm a horizontal sliding tube holder E. It can also slide vertically upon upright A, to which it may be fixed by a thumb-screw.

E is one of two tube holders which can slide backwards in a **V**-shaped groove upon the arms of C. It can also be raised or lowered by sliding the whole of C on upright A. There is one on each side for holding the tube opposite to the right or left eye, as may be required. To simplify the diagram

the tube is not shewn, but it should be provided with a protective shield and cylinder diaphragm.

F points to cross wires fitted across a wooden frame. There is one such frame for each arm of B.

H is a sighting point. In the side view it is pushed aside; on the view looking downwards it is pulled out in position. There is one on each side, and they are used for sighting and setting the tube. The observer looks through the **V**-notch, and adjusts the tube till he gets the focus point mark of the antikathode in line with the crossing of the wires F on each side of B. This does away with the necessity of a screen or other special device for centering the tube.

K indicates the centre line extending from the sight point H through the cross wires F to the focus point mark of the antikathode of the tube.

I is a piece of wood that slides horizontally to clamp the patient's head to the side of the support box. The patient's head may be placed on either side of the clamp I, according to the eye which it is desired to examine.

J indicates outline of the patient's head in position for examination of the right eye, in which case the X-ray tube would be placed in holder E towards the left side.

A small piece of lead wire is stuck to the lower eyelid of the eye to be examined, and carefully adjusted, so that the upper end of the wire will be exactly opposite the centre of the pupil when the patient is looking straight forward, as at a distant object.

The patient takes his position in the chair D, the head resting in box B, and to the appropriate side as in the figure. B is raised or lowered till the horizontal wires are in line with the apex of the fuse wire, which is fixed opposite the centre of the pupil, and clamp I is adjusted. Then C, bearing with it the tube, is raised or lowered, and the tube is adjusted in its holder E, till the focus mark on the antikathode of the tube is in line with the crossing of the wires F, the slide of the tube holder being meanwhile in mid-position, as indicated by M. A photographic plate in envelopes is then placed on the outside of the opposite opening and pressed hard against the cross wires. For a quadrant mark a lead number may be affixed at the lower right-hand corner, thus numbering the plate as well as denoting its orientation.

The cross wire frame adjoining the tube is removed. The

tube holder slide is pushed forward till M corresponds with O (3 cm.). The patient is directed to look straight forward at a mark on the wall at the same height as his eye; and the first exposure is made. A fresh plate is then substituted for the exposed one; the mark M is pushed backwards till it corresponds with P (6 cm. from O), and the second exposure made.

The distance between O and P being 6 cm. the plates after

Fig. 168.—FOREIGN BODY IN THE ORBIT.
(Details of exposure of radiogram slightly different from description in text.)

development may be placed in a stereoscope. Being of small size they may be viewed in a suitable hand stereoscope, or contact prints made from them may be so viewed. Measurements are, however, generally also made by the use of Mackenzie Davidson's cross thread localiser or by calculation, as already described. A cross thread localiser for eye cases may be permanently set, as the distance between the focus point of the antikathode and the plate, and the length of

traverse of the tube between its two positions, are constant for all exposures.

Fig. 168 represents the record obtained on one of two plates so exposed. From that directly we may measure the vertical position of the foreign body relative to the horizontal meridian of the eyeball, if the horizontal wire has been set to coincide with that.

By the cross thread localiser, or by calculation, the position of the vertical lead wire attached to the eyelid and of the foreign body, each relative to the vertical cross wire, are ascertained,

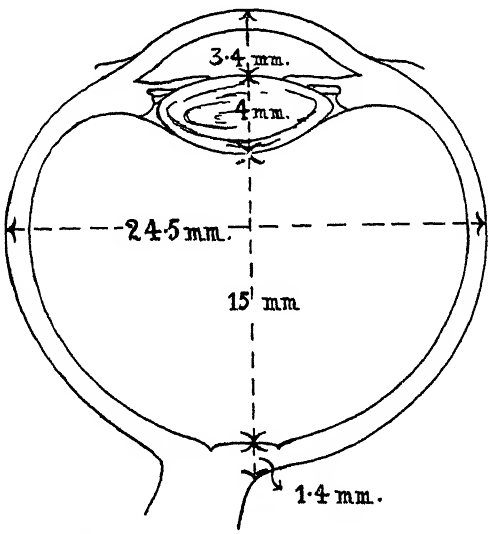


Fig. 169.—DIAGRAM OF EYEBALL.

and from those data the antero-posterior depth of the foreign body from the lead wire, and concurrently from the front of the eyeball, may be deduced. In making the calculations, 1 mm. is generally allowed for the distance between the lead wire and the front of the eyeball. Then, in a similar way, the distance of the lead wire from the plane of the plates during exposure is measured, and the distance of the foreign body from the same plane. From these two distances the position of the foreign body relative to the vertical meridian of the eye is calculated.

Thus, measurements relative to the three axial planes of the eyeball are obtained, and from reference to the measurements of an adult eyeball, as given in Fig. 169, it can be

determined whether the foreign body is situated in the eyeball or in the surrounding structures, and its position can be indicated with exactitude.

The average diameters of the adult eye are :—

Antero-posterior - - - -	24·0 millimetres
Transverse - - - - -	24·5 ,,
Vertical - - - - -	23·5 ,,

Sir James Mackenzie Davidson describes in his book on Localisation a similar method of localising foreign bodies in the eyeball or orbit, which differs in detail from the above method.

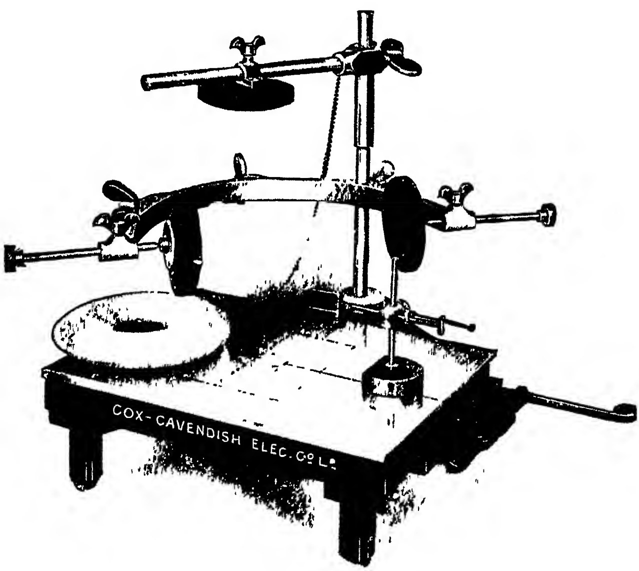


Fig. 170.—Dr. Sweet's Eye Localiser.

The principles, however, are the same, and the method here described has proved itself most serviceable in practice.

(ii) **Sweet's Localiser** is a convenient specialised form of localiser for eye work. Fig. 170 shews its main features—the horizontal plate holder in which the two halves of a plate may be exposed in succession, a head rest and clamps to secure the patient's head, and a small pedestal carrying a fork-shaped indicator, of which a record is made in each exposure, so as to furnish a relative guide to the position of the foreign body, also recorded on each half of the plate. With the patient's head in position the indicator is set in alignment with the centre of the cornea of the eye to be examined (which will of course be the

one nearest the plate), and so as just to touch the eye, after which, by release of a spring, the horizontal part is withdrawn to a distance of exactly 10 mm.

The X-ray tube may be placed at any convenient distance above the patient's head, and its shift between the two exposures need not be measured.

After development, the records of the foreign body and of the indicator are transferred to a special chart supplied with the instrument, and from their relative positions is deduced the position of the foreign body relative to the axes of the eyeball, as described in the preceding section.

Other special arrangements devised for eye work merit equal attention, but it is impossible to describe the details of each, and the foregoing explanation of principles should make their application readily understood.

CHAPTER VIII

DIAGNOSIS—GENERAL

It cannot be too strongly insisted upon that in this, as in all methods of diagnosis, it is essential to acquire first an *accurate knowledge of normal appearances* and of all variations within normal limits. This can be attained only by study of radiograms taken under various conditions, and most effectively so when those conditions are known at first-hand by observation of them before and during exposure of each radiogram in question. Screen work demands a similar experience for its efficient utilisation.

In a radiogram is discerned *no positive evidence* or indication of disease ; all that is discerned is a departure from the normal, so that it is essential that an observer should fully understand normal appearances before he attempts to recognise or interpret the abnormal.

Comparison of radiograms of known conditions with *pathological specimens* will be found invaluable, and, where the subject of a radiogram becomes available, either at *operation* or in the *post-mortem* room, no opportunity of such direct comparison should be missed.

In the absence of, or in addition to, such opportunities, much may be learned from study of pathological *museum specimens*, this enabling the radiologist to visualise more readily the actual changes imprinted on the radiogram.

The *correlation* of pathological changes with radiographic appearances can only be arrived at, however, by such direct study, particularly of actual radiograms, and no attempt is made in the following notes to recapitulate pathological processes nor effects.

It should be superfluous to impress the necessity of practical experience in any branch of medical work; but the number of persons who seem to think that they are, or should be, able to read any radiogram without any special study or experience, impels emphasis on this point for the benefit of those who really wish to make the most of the very valuable

assistance that may be derived from radiological observations and records.

In all cases the evidence of radiology should be taken *in conjunction* with other observations or methods of diagnosis.

In certain instances diagnosis of a condition may be made from X-ray examination alone. In some instances earlier evidence of disease is thus obtained than by any other means; but the method is of most general use in helping to define, differentiate, or confirm conditions recognised or suggested by other means of diagnosis.

Fig. 171.—Reproduction of Radiogram as seen in a "Negative" Plate or Film.

Fig. 172.—Reproduction of Radiogram as seen in a "Positive" Print, on a Fluorescent Screen or in usual Book Illustration.

Negative evidence, that is, the absence of any change from the normal, is also most valuable as indicating the absence of organic disease in the part examined.

In the early study of radiology attention will naturally be focussed mainly on the production of reliable radiographic records; as the student becomes familiar with the apparatus and processes, his attention will gradually be diverted to the problems of interpretation of those records.

As already mentioned, this can be thoroughly done only by one familiar with the whole subject, but, on the other hand, many practitioners of medicine and surgery like to be able to

appreciate the radiological signs and to combine and correlate those with clinical signs and symptoms elicited by other means.

It is predicted by some that radiology will, in course of time, cease to be a speciality and become an essential part of the general equipment of every medical practitioner. The latter development is rapidly occurring, but all the more is there a call for special and intensive study of radiology on the part of a number of special workers, so as to gain full and increasing advantage of its possibilities. Trained radiographers may relieve the medical worker of the necessity for detailed knowledge of the technique of production, but the whole value of radiology inevitably depends upon intelligent interpretation by trained observers of the radiograms produced.

The interpretation of radiograms in general has been discussed in an earlier chapter (pp. 207-211); in the following notes this is applied to the different systems, and different parts of the body, in series.

Typical radiograms are reproduced of many parts and conditions, those having been selected for their educative value and also for possible reference in actual diagnosis. It is obviously impossible in a work of this nature to include every type and variety of disease condition, but the series reproduced should serve as a key to further study, and should suggest the diagnosis in many conditions similar to, though not identical with, those illustrated.

In any case of doubt concerning a *bilateral* part of the body, a radiogram should be made of the corresponding part of the sound side for comparison.

In examining the illustrations as reproduced, it must be remembered that those are *positive-like prints*, and that the appearances in plates or negatives will be reversed. Inasmuch as faithful reproduction of radiograms is very difficult, learners are strongly advised to take every opportunity of studying actual radiograms.

NOTE.—In describing radiographic appearances "*diminished density*" corresponds to "*increased transradiancy*" of exposed tissues. The term may be transferred directly to the "*positive*" reproductions of the illustrations in this book, to photographic prints, or to screen appearances, but must be *reversed* when considering original "*negative*" plates or films. Figures 171 and 172 shew the two contrasting conditions, and the descriptions

in the following notes have reference to the positive appearances, unless otherwise indicated.

In the following notes various parts, diseases, and conditions will be found classified under systems as here summarised:—

Osseous System: Bones, Joints, and Muscle. (Chap. IX.)

Respiratory and Circulatory Systems: Lungs, Heart and Aorta, Mediastinal Glands and Tumours. (Chap. X.)

Orthodiagraphy: (Chap. XI.)

Alimentary System: Gastro-intestinal, Liver, and Gall Bladder. (Chap. XII.)

Urinary System: Kidney, Ureter, and Bladder. (Chap. XIII.)

CHAPTER IX

DIAGNOSIS—OSSEOUS SYSTEM

BONES AND JOINTS

Examination of bones and joints forms the routine work of most X-ray installations, and comes to be relied upon more and more by surgeons as they understand more of its possible service. So definite and useful is the evidence thus obtained of obscure injuries, that the fear has been expressed that younger surgeons may learn to depend upon it to the exclusion of other methods of diagnosis, of which it is well that they should also gain experience.

(*a*) **Possible fallacies** are numerous, and should be carefully noted.

(i) The grosser lesions, as in fracture and advanced disease, are usually recognised easily from the displacement of parts or gross alteration in outline and density of shadow, as seen either on screen or radiogram; but a fracture may exist without displacement, and early disease shew but little alteration, so that

such may be readily overlooked in a screen examination. *Thus, a screen examination should never be relied upon for negative evidence to refute positive symptoms.* The radiogram reproduced in Fig. 173 well illustrates the necessity of exposing a plate in all doubtful cases before expressing an opinion. The patient had some disease of the tibia, and was brought to hospital on the apparent occurrence of a spontaneous fracture. Careful inspection by the fluorescent screen shewed no evidence of a fracture, but the radiogram gave clear evidence of a transverse fracture, without displacement or separation of the fragments

Fig. 173.—SPONTANEOUS FRACTURE (NOT EVIDENT ON SCREEN EXAMINATION).

This rule applies also in examinations for other conditions, and very rarely is it justifiable to make a report on screen examination alone.

The benefit of corroboration and amplification of screen appearances by a radiogram is pointed out later in relation to diagnosis of lung conditions; and, even in such a relatively simple question as presence of a foreign body, a negative finding should not be relied upon without exposure of a film or plate over the suspected part.

(ii) *Reliance on a single view* of a part may lead to error, unless the part has been previously screened carefully in all positions, and the radiogram made with the part in that position found to shew the lesion most plainly. On the other hand, care must be taken not to give an exaggerated view of the lesion. (See notes on fractures, on page 313.) The danger of a single view is well illustrated in Fig. 174, and also in Fig. 250, on page 316. In such cases a double view may be taken on one plate by protecting, in succession, each half of the plate from the rays by sheet lead, or other opaque material, while the

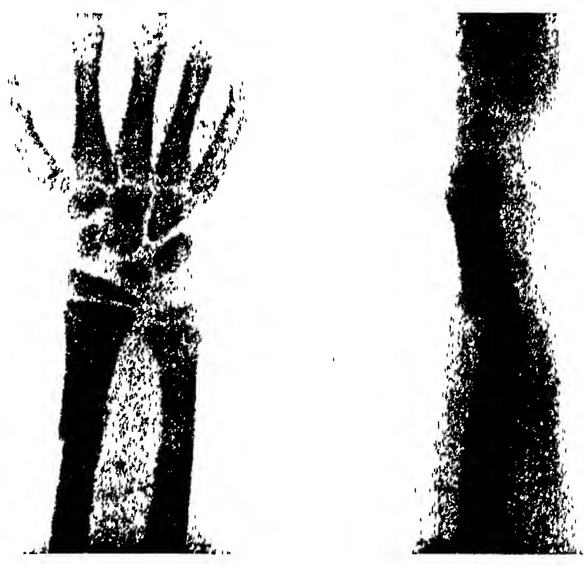


Fig. 174.—POSSIBLE FALLACY OF SINGLE VIEW.

other half is being exposed, as explained and illustrated on page 219.

Other possible fallacies in interpreting views of special parts are referred to in the following sections, in which those parts are separately considered.

(iii) *Incomplete ossification* in young bones is a familiar source of error, and is referred to further on page 259.

Extra, and possibly *separate*, *centres of ossification* must also be borne in mind, particularly in examining the hands and feet. Similar appearances in both limbs will usually indicate the nature of such an abnormality, and on pages 276 and 293 attention is drawn to the usual situations of such centres.

(*b*) **Normal Appearances.**—In a radiogram of a *long bone* (Fig. 175) will be seen the *central medulla* which, being relatively transradiant, is shewn on a plate or film by a relatively dark shadow (negative effect) crossed by a few lighter strands corresponding to trabeculæ.

In prints, the medulla appears as a light central strip (positive effect) crossed by darker strands. Those strands merge into the *network of cancellous tissue* at each end.

The medulla is bounded by the *compact layer* of the *cortex*, which is shewn (in the negative) by a white line, broadest along the middle of the shaft and merging into a narrow line forming a boundary at each end between the network of cancellous tissue and the articular cartilage, which normally leaves no record on a radiogram.

Occasional cyst-like depressions in the cortex appear as darker oval areas in the medullary shadow, or as darker projections across the inner outline of the cortex, but those have no pathological import.

Spongy bone, as in the carpus and tarsus, or at the ends of a long bone, as in Fig. 175, shew a thin dense *cortex* bounding a continuous network of *cancellous tissue*, with occasional areas of denser shadow of no pathological import.

Normal bone, either long or spongy, varies in thickness of cortex and texture of cancellous tissue in different individuals and in individual bones, but the *cortex* in each bone should be of *uniform density* and *regularly graded thickness* with a *smooth regular outline;* whilst *medulla* and *cancellous tissue* should be *regular and uniform in arrangement and density*, except for the areas mentioned above.

Flat bones, as in the scapula or cranium, show only *lighter strips* of variable width, corresponding to denser borders and ridges, and *darker channels* corresponding to grooves of blood vessels.

Those normal appearances should be carefully observed and studied so that departure from the normal, as indicating the effects of disease, may be readily and definitely detected.

Fig. 175.—Radiographic Appearances (negative) of a Long Bone, and of Sections Shewing Spongy Bone.

Plate I.

S

Fig. 176.—CHILD'S JOINT, SHEWING INCOMPLETE OSSIFICATION, AGE 7.

Fig. 177.—ADULT JOINT, AGE 21.

Plate II. Fig. 178.—OLD JOINT, SHEWING ATROPHY OF BONES. AGE 73.

Cartilage covering articular surfaces of the ends of bones is normally transradiant and indiscernible in a radiogram, as also are *ligaments* and *synovial membrane.*

Between the ends of adjoining bones constituting a *joint* the cartilage appears as a clear *space*, which in children is especially wide owing to *incomplete ossification* of the epiphyses. The *age* of a patient is therefore a most important factor to know, as will be evidenced by the notes in the succeeding section and from the diagrams reproduced later of each joint.

Normal bone may be expected from 20 to 40 years of age; before 20 incomplete ossification must be looked for; after 40 atrophy commences, until in *old age* the compact layer of the cortex is definitely narrower, with a corresponding increase in transradiancy, and the cancellous tissue more delicate in structure and "sketchy" in appearance.

Similar atrophy and absorption of lime salts follow *disuse* of bones, and should be looked for in such cases.

The appearance of a normal adult joint is reproduced in Fig. 177, whilst the differences to be expected in young and old subjects respectively are shown in Figs. 176 and 178.

(*c*) **Age of Patient.**—The age, already referred to, regarding normal bone, on page 255, must be specially noted in all cases, for in young subjects there is a special difficulty met with in the presence of *unossified cartilage* in the parts, and of ossifying centres in *epiphyses* not yet united to the diaphyses.

Where doubt exists on this point, or any other, as to its abnormality, a decision can usually be come to by comparison with a corresponding view of the same part on the other side of the patient—that is, compare right with left. Otherwise the normal line of cartilage between an ununited epiphysis and a shaft may be mistaken for a fracture or dislocation (see Fig. 242).

In the table opposite will be found a list of the important centres of ossification, with dates of appearance and of union, and in the serial notes on each part of the body, which follow this, are included figures illustrating those centres. A series of radiograms selected to shew the appearances of various joint regions at different ages would be of great value for reference, but such inclusion would extend this work beyond reasonable limits. Reference to the diagrams should, however, be sufficient to guide the radiologist to a solution of most difficulties in this direction. One source of frequent error, due to unossified cartilage, is illustrated in Fig. 185 of the clavicle, and is explained in the adjoining text, whilst an epiphysis of the os calcis, shewn in Fig. 219, surprises most observers when they first notice it. Particular attention should always be paid to the epiphyses of children and young subjects up to the age of complete ossification of the part concerned.

Injuries are common about those regions, and future growth of the bone depends largely upon the integrity of the "*epiphyseal line*" or "*zone of proliferation*," so that for purposes of prognosis it may be most important to know the condition of that region. Especially may this be so if legal liability is involved.

In *rickets*, as noted later, the borders of this zone are very irregular, while in *achondroplasia* the opposite condition of over-defined borders appears, and in such general diseases the appearance of the epiphyseal region of young bones may lead to an earlier diagnosis than would otherwise be possible.

Comparison with corresponding joints of the other side of the patient will be of no service here, since all joints are probably more or less involved, but knowledge of normal appearances, and comparison with similar radiograms from normal children of the same age, should settle the diagnosis.

EPIPHYSES—CENTRES OF OSSIFICATION.

	Approximate Year of Appearance	Approximate Year of Union.	Reference to Figure.
Clavicle: sternal end	19	25	
Scapula: coracoid process	1	16	
acromion (2 centres)	15	24	
lower angle and base	17	25	188
Humerus: upper end: head	1		
great tuberosity	2 } 6	20	
lesser "	4		
capitellum	3		
trochlea	11	17	
external condyle	13		194
internal condyle	5	18	
Radius: head	5	17	
lower end	2	18	
Ulna: olecranon	10	20	
lower end (styloid)	4	20	
Carpus: os magnum	1		
unciform	2		
pyramidal	3		
lunar	4		
trapezium	5		197
scaphoid	6		
trapezoid	7		
pisiform	12		
Metacarpals: inner four at distal end			
first at proximal end	4	20	
Phalanges: at proximal end			
Pelvis: ilium			
ischium	ante-natal	13 } 16	
pubis		8	
ischial tuberosity			
anterior superior spine of ilium	17	24	209
symphysis pubis			
iliac crest			
Femur: head	1	19	
great trochanter	4	18	
small trochanter	14	17	
lower end	ante-natal	20	
Patella	3	18	
Tibia: upper end	ante-natal	22	212
lower end	2	19	
Fibula: upper end	4	24	
lower end (malleolus)	2	21	
Tarsal: astragalus	ante-natal		
os calcis			
os calcis, posterior epiphysis	10	16	
cuboid	birth		
external cuneiform	1		219
internal "	3		
middle "	4		
navicular "	5		
Metatarsals: outer four at distal end			
first at proximal end	5	19	
Phalanges: at proximal end			

(*d*) **Special Parts.**—As has been stated in an earlier chapter, it is necessary to decide for each part a *standard position* in which it should be placed for radiographic exposure, unless special circumstances dictate otherwise.

From consideration of anatomical relations, and from collective experience of radiographers, certain positions are recommended. Those are illustrated and explained in the following sections. Where external landmarks are not suffi-

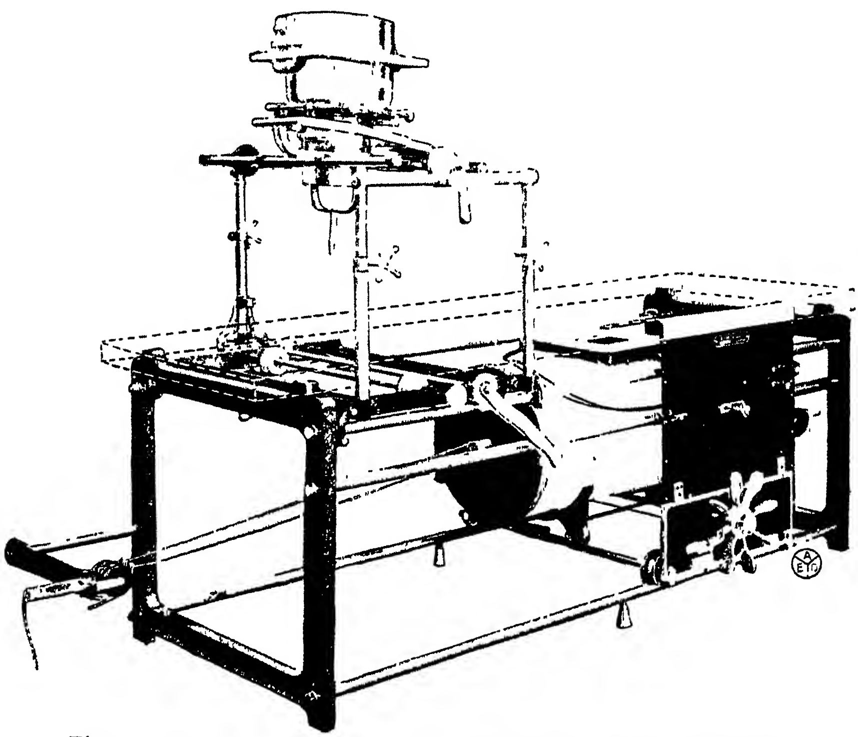


Fig. 179.—Stirrup and Pointer for Centering Tube over Part.

cient indication, it may be advisable that the part should be viewed by fluorescent screen before proceeding to expose a plate over it. By this means the tube, set below the patient, may be properly set, the part arranged to give the desired view, and the diaphragm suitably adjusted before the exposure is made.

In the sections which follow the different parts of the body are taken in series, and there is indicated for each part the position found suitable for exposure to elicit most precisely the requisite information regarding its conformation and condition. Notes are made of points demanding special attention, and, where required, figures are reproduced of their radiographic appearance.

Such reproductions are included only to illustrate special points referred to in the text, and are chosen, not for their general excellence or "beauty," but for their clear illustration of those points.

A number of radiograms are included of normal joints in standard positions; where a part is not specially mentioned, it is assumed that the general principles previously discussed will serve as sufficient guide.

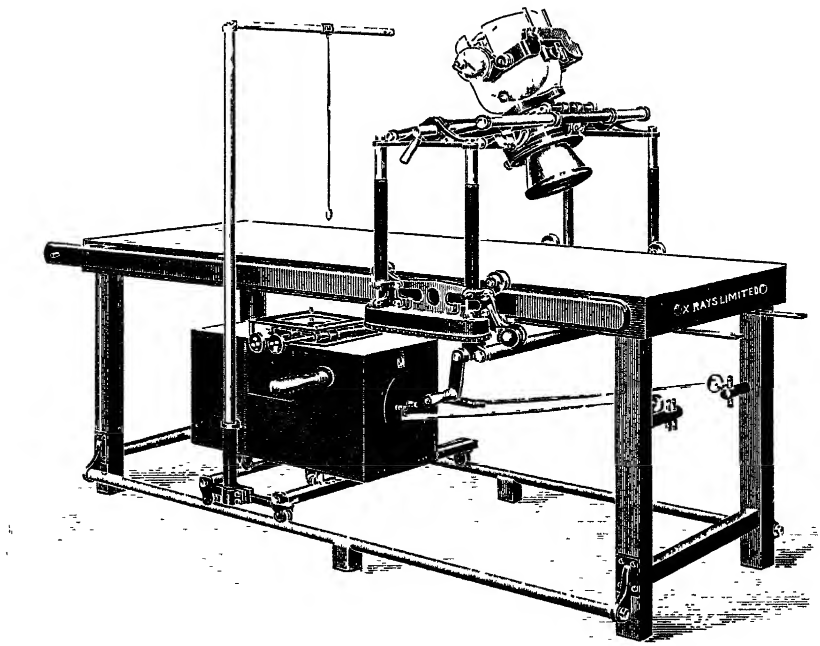


Fig. 180.—Plumb-bob for Centering Tube under Part.

Central Ray Directors.

Various arrangements are in use for *centering the tube* over the desired part without the use of a screen, and the choice depends upon the preference of individual operators.

The *stirrup and pointer*, illustrated in Fig. 179, is probably the most serviceable device for a tube set above the table or carried on a tube stand, and this can be used in any direction.

The *plumb-bob* arrangement, shewn in Fig. 180, is a common device for centering a tube carried in a tube box travelling under the table, but is only applicable in the vertical position.

A simple device, of which a serviceable form was described by Mr. Campion (in the "Archives of Radiology and Electro-therapy" for September, 1918), may be attached to the front of any tube box, as shewn diagramatically in Fig. 181.

The small arms carrying opaque metal objects—balls or rings—at their free extremities, are set so that each of those objects is in the line of the central ray of the tube set centrally in the tube box (see page 135), and in that position they are fixed. If then the tube box be set so that those two objects coincide with pre-arranged points on either side of a

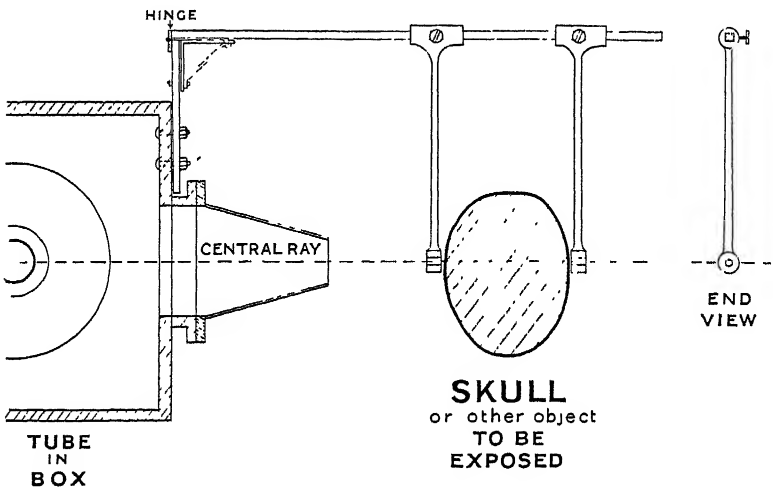


Fig. 181.—Director (Campion's) for Setting Tube with Central Ray in Prescribed Axis.

part to be radiographed, it will be known for certain that the central ray will pass between those two points.

For precise setting this may be most useful, as in radiography of the skull, particularly of a deep-lying part like the sella turcica.

A hinge allows convenient removal of the objects whilst the exposure is being made.

Necessity for steadiness of the part must always be remembered, and sand-bags or other such supports should be freely used for relatively long exposures.

Even for short exposures support of a part may often be necessary to prevent the involuntary tremor so readily set up in a part in any position other than that of complete rest.

Shoulder.—With the patient lying on his back and the tube under the table, the tube should be set so that the space (indicated in Fig. 182 by letter A) between the head of the humerus and the acromion process appears at its maximum. The diaphragm should then be adjusted to illuminate the area included in the circle shewn in the figure, with which circle the head of the humerus should be practically concentric.

The plate should be placed on front of the shoulder, as shewn in the figure, and during exposure pressure may be exerted on the plate as it rests on the pectoral muscle and

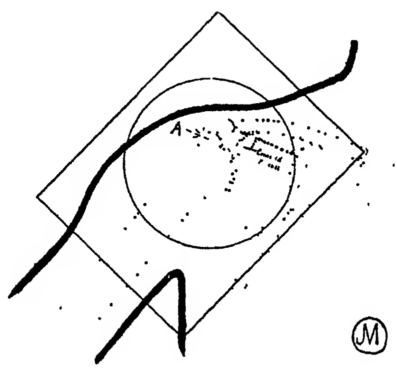


Fig. 182.--SKETCH OF POSITION FOR SHOULDER JOINT.

rotundity of the shoulder, endeavouring by depression of the former to keep the plate as nearly in a horizontal plane as possible. With the tube above the table the tube should be centred over a point taken as the geometric centre of the rotundity of the shoulder. This should be over the centre of the glenoid cavity, and if that can be felt it may serve as a useful guide. In this position the plate will rest on the table, in the direction shewn in Fig. 182, and the shoulder should if possible be pressed down against it.

Fig. 183 reproduces a radiogram of a shoulder joint set in the normal position with the arm by the side. The coracoid process, outlined and named in Fig. 182, is seen somewhat indistinctly in this radiogram because it is superposed on the neck of the scapula; and on account of its direction it is markedly foreshortened.

It may be well seen in a radiogram taken in another position suggested for the shoulder. With the arm raised the tube is

Fig. 183.—Shoulder Joint in Normal Position.

set in the axilla and the plate placed on the upper aspect of the shoulder, thus obtaining a view of the shoulder in a plane more or less at right angles to the other.

The position, however, is awkward and in many injuries impossible.

The vignette surrounding Fig. 183 may be somewhat misleading as to the centering of the radiogram, but, in this and similar figures, the circle of the vignette has no relation to the circle of exposure.

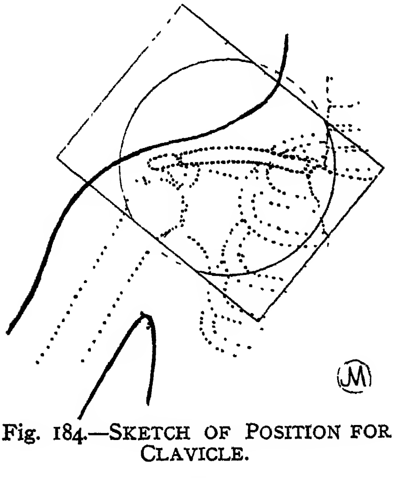


Fig. 184.—Sketch of Position for Clavicle.

Clavicle.—The tube should be centred over the mid-point of the clavicle, as shewn by the circle in Fig. 184, and the plate set as shewn in the figure, its inner end being pressed down on the pectoral muscle.

With the tube set above the table the patient may be turned on his face, but apposition of the plate to the clavicle is thus difficult, and if a tube cannot be placed under the patient a serviceable radiogram may be secured by placing the plate under the shoulder of the patient, set as in Fig. 184, whilst he lies facing the tube.

Fig. 185 represents a radioscopic view of a clavicle. At the articulation of the clavicle with the acromion process should be noted a clear triangular notch with apex downwards. This corresponds to the intervening articular cartilage and projecting

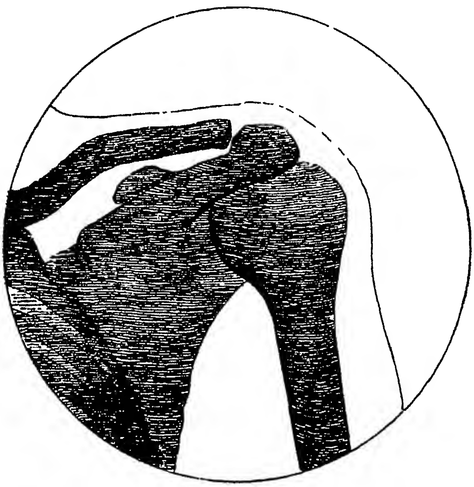


Fig. 185.—Acromio-Clavicular Articulation (from Radiogram).

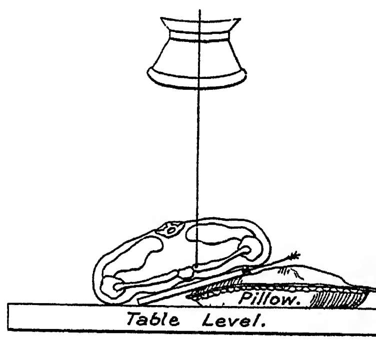


Fig. 186.—Position for Sterno-Clavicular Articulation.

synovial membrane, which is here very redundant. The appearance shewn is quite normal, but has frequently been mistaken by the uninitiated for a fracture of the outer end of the clavicle or a dislocation of that bone from the acromion process.

For a clear view of the *sterno-clavicular articluation* the patient should be placed on his face, and turned so that the spine is not vertically over the articulation.

The position is represented diagramatically in Fig. 186, from a paper by Dr. Knox in the "Archives of Radiology and Electrotherapy."

Scapula.—The patient should lie on his back with the plate under the scapula, so that his weight may maintain the desired apposition. For a general view, the tube should be centred over a point about 4 in. below the mid-point of the clavicle (about 3 in. above the male nipple), so as to include the whole scapula; but more often a definite region such as the glenoid, acromion, or coracoid will be indicated for inspection, and the tube should be centred accordingly. For the body of the scapula a very soft tube will be required, and an under-exposure (as reckoned for other parts); otherwise the thin

Fig. 187.—CONGENITAL ELEVATION OF SCAPULA.

bone will be completely penetrated and no impression of it left on the plate. For a similar reason it is essential that the plate or film be placed in direct apposition to the back of the patient.

Congenital elevation of the scapula is illustrated in Fig. 187. Such a scapula is seen to be shorter from above downwards and generally misshapen, whilst it lies nearer to the spine than its fellows, and may be seen to be restricted in its movements if observed by screen, or if radiograms be made in its extreme positions.

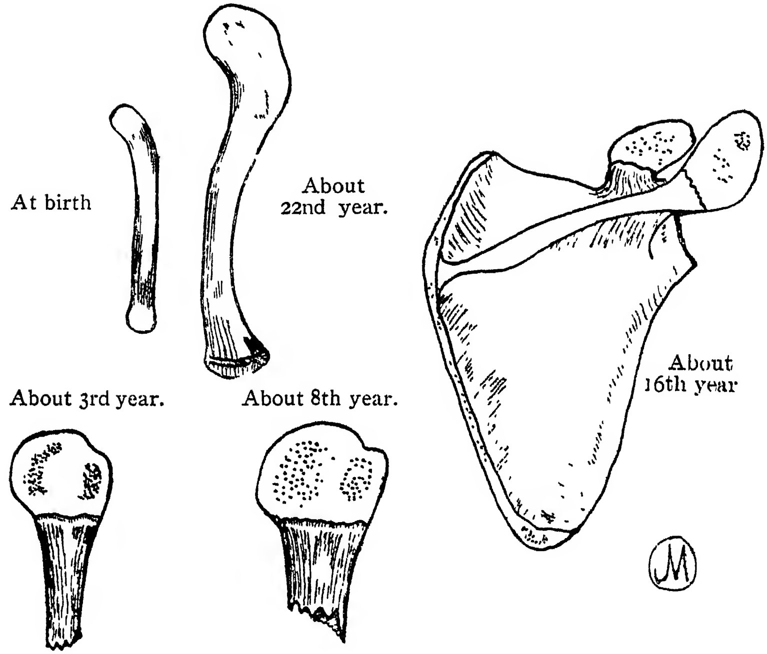


Fig. 188.—Centres of Ossification and Epiphyses about Shoulder.

Clavicle.—At birth is osseous in its shaft and cartilaginous at both ends. Acromial end ossifies from the shaft. Sternal epiphysis appears about the eighteenth to twentieth year, and unites to the shaft about the twenty-fifth year.

Scapula.—Note the separate centre for the coracoid process, which appears in the first year, and unites to the body about the sixteenth year. There is also a second separate centre (subcoracoid), which appears about the tenth year, and forms the base of the process and the upper angle of the glenoid cavity. In the acromion two epiphyseal centres usually appear about the fifteenth year, coalesce soon afterwards, and unite to the body between the twenty-second and twenty-fifth year. A centre at the lower angle and a strip along the base appear about the seventeeth year, and unite about the twenty-fifth year.

Humerus.—At birth only the ends of the bone are cartilaginous. The nucleus for the head appears in the first year; for the great tuberosity in the second or third year; for the lesser tuberosity in the fourth or fifth year, or is continuous with the greater. These nuclei join together about the sixth year to form an epiphysis, which unites to the shaft about the twentieth year.

Elbow.—For a *lateral* view the joint should be flexed at right angles, while the upper and lower arm lie in the same horizontal plane, and the hand is turned with the palm downwards.

The patient may either lie on the couch, or, kneeling at the side of it, place the arm on the couch, and lower himself till the whole upper arm rests on it.

This position will serve for either side of the joint, if the plate be placed in contact with that condyle of which the most distinct view is desired, and the tube centred over or under the opposite condyle.

Fig. 189.—Normal Elbow—Lateral View.

Fig. 189 represents a view so obtained, with the transverse axis of the end of the humerus perpendicular to the plate.

To obtain a better view of the lower end of the humerus, or possibly of the head of the radius, an antero-posterior view is desirable. For this the joint should be fully extended (if possible), the palm of the hand turned up, the arm laid flat on the couch with the width of the elbow parallel to its surface, and the plate placed in front of, or behind, the joint according as the tube is below or above the couch. The tube should be centred over the joint space, which may be taken as under the line of the three prominences formed by the condyles and olecranon.

Fig. 190 shews this position of the joint.

Where the *joint is fixed* in a flexed position an *antero-posterior* view of the joint may be obtained by resting the point of the elbow on the centre of a plate, and setting the tube above in a

Fig. 190.—Elbow—Antero-Posterior View.

position bisecting the angle of the joint, as shewn in Fig. 191. The upper and lower arm should form equal angles with the plate, which should be of small size, since on a large plate parts included distal from the joint will be greatly distorted.

If the view be desired to include more particularly the constituent bones above or below such an elbow, that part of the arm should be placed parallel to the plate, and the tube should be set perpendicularly above a point slightly to that side of the joint. Fig. 192 shews an arm set for a view of the lower end of the humerus along with the elbow-joint, and Fig. 193 reproduces the resultant radiogram.

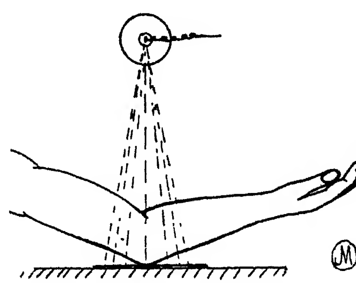


Fig. 191.—Position for Ankylosed Joint.

Fore-arm.—For a good view the arm should be set with the hand fully *supinated* (that is, with palm upwards), since in that position the radius and ulna are parallel and each plainly seen, but it must not be omitted to view the part also in the other position for possible displacement (see Fig. 174).

Fig. 192.—Setting of Patient and Tube for Elbow and Humerus.

Fig. 193.—Elbow from Setting as in Fig. 192.

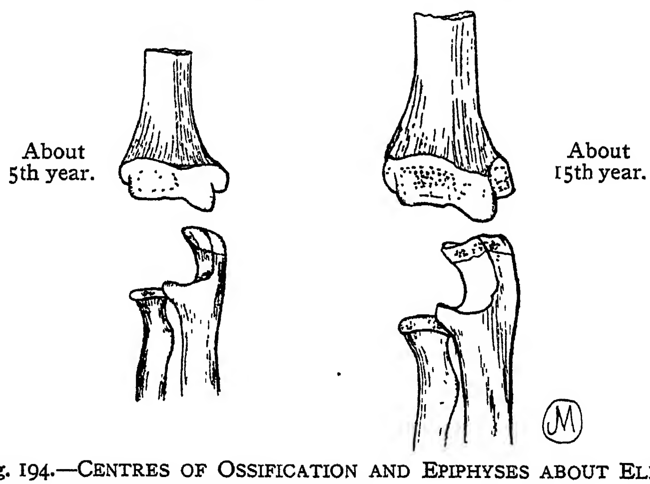


Fig. 194.—Centres of Ossification and Epiphyses about Elbow.

Humerus.—A nucleus for the **capitellum** appears in the second year; for the **internal condyle** in the fifth year, for the **trochlea** in the eleventh or twelfth year, for the **external condyle** in the thirteenth or fourteenth year. The **internal condyle** forms a **separate epiphysis**, which unites to the shaft in the eighteenth year. The other three **nuclei coalesce** to form an epiphysis, which unites to the shaft about the sixteenth or seventeenth year.

Radius.—A nucleus appears in the head about the fifth or sixth year, and the epiphysis unites to the shaft about the seventeenth or eighteenth year.

Wrist.—With injury in this region the part should be carefully screened in all positions to detect possible fracture or dislocation of the radius, ulna, or carpal bones, and to decide the proper position for a radiogram to show most clearly the lesion present. As a rule, the best view is obtained with the plate placed on the back of the joint; but, with the tube above, the hand may be more conveniently placed palm downwards on the plate.

Fig. 195 shews a view with the hand in full ulnar deviation, the articulations between the individual carpal bones being best

Fig. 195.—WRIST JOINT WITH HAND IN ULNAR DEVIATION.

seen in this position. Alteration in the position of the hand makes a marked difference in the view obtained, so that care must be exercised to avoid comparison of dissimilar views. For definite injury a position should be chosen by previous screening to bring out most clearly the injured part.

For general purposes the tube should be centred over a point midway between the tips of the styloid processes of the radius and ulna.

Lateral views of the wrist may be of considerable value, and certain special positions are useful so as to secure good views of certain of the carpal bones and articulations.

One such position, for exposure of the trapezium, trapezoid and scaphoid, has the thumb laid with its dorsum flat on the

table, while the hand is turned with its ulnar border facing directly upwards, the vertical ray being directed into the flexure thus formed between the thenar eminence and the palm of the hand. Intimate acquaintance with the anatomy and surgery of the articulation is essential to diagnose some of the obscure lesions met with, many of which are very difficult or impossible to diagnose by any other means. Views of carpal injuries are notoriously hard to reproduce, the reproduction so obscuring the slight differentiation relied upon that little is usually gained from such reproductions. From surgical dia-

Fig. 196.—Double View of Fracture of Finger.

grams much aid in interpretation may be obtained, but in this proficiency can come only through experience.

Fracture of the lower end of the radius, with or without separation of the ulnar styloid (*Colles's fracture*), is a familiar injury met with. Impaction of the shaft of the radius into the cancellous tissue of the lower fragment may obscure the true nature of the lesion, but in a good radiogram evidence of this will always be found, though a screen view may not reveal it.

As in all fractures, the tube should be centred over the seat of the fracture, and, if the precise site is ascertained only after exposure of a plate, a second plate should invariably be exposed if the fracture does not happen to be accurately centred in the first.

Hand.—Apart from the carpal articulation, radiography of the hand presents no special difficulty. The best view is ordinarily obtained with the plate on the back of the hand, closer apposition to the bones being possible on that aspect.

Injuries to the metacarpal bones are occasionally difficult to diagnose precisely without the assistance of X rays, and even phalangeal lesions call at times for elucidation. Fractures near the joints may thus be differentiated from dislocations. Fig. 196 reproduces a radiogram of a fracture not previously diagnosed, though of some duration, persistent swelling obscuring the actual lesion.

8th year.

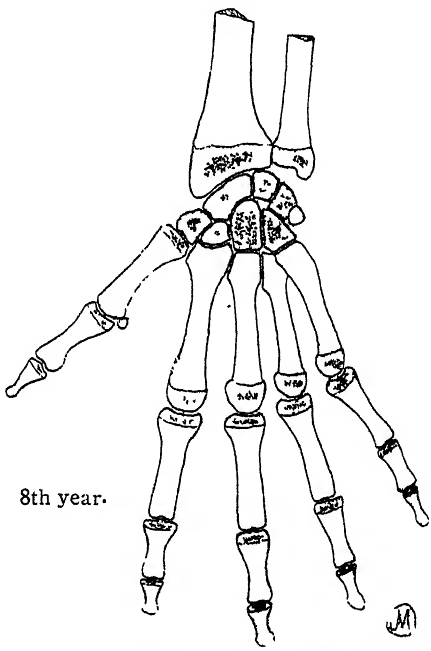


Fig. 197.—Centres of Ossification and Epiphyses about Wrist and Hand.

Radius.—Nucleus appears about the end of the second year. Epiphysis unites to the shaft about the eighteenth to twentieth year.

Ulna.—Nucleus appears in the fourth or fifth year. Epiphysis unites to the shaft about the twentieth year.

Carpus is entirely cartilaginous at birth. A nucleus appears in the **os magnum** in the first year, in the **unciform** in the first or second year, in the **pyramidal** in the third year, in the **trapezium** in the fifth year, in the **lunar** in the fifth year, in the **scaphoid** in the sixth or seventh year, in the **trapezoid** in the seventh or eighth year, in the **pisiform** in the twelfth year.

Metacarpals and Phalanges.—Each has one epiphysis, of which the nucleus appears from the third to the fifth year, and which unites to the shaft about the twentieth year. The **inner four metacarpals** have the epiphysis at the **distal extremity**. The **first metacarpal** and the **phalanges** have the epiphysis at the proximal extremity. The first metacarpal may also have a distal epiphysis at the age of seven or eight years.

(*Also see following section.*)

Variations and Extra Ossicles in Wrist.—Variations are frequently found in the bones of the wrist and hand. Supernumerary digits naturally cause no difficulty, but care must be taken to avoid mistaking variations in the carpal bones for results of injury. Such confusion is especially apt to arise in the presence of abnormal centres of ossification, which in an incompletely ossified carpus will appear as separate bones, and which may remain separate so as to produce a bipartite normal bone or an abnormal extra ossicle.

Anatomy textbooks describe the varieties of those, and from the information in Quain's "Anatomy," the opposite figures have been constructed as a reminder of the possible presence of such extra centres.

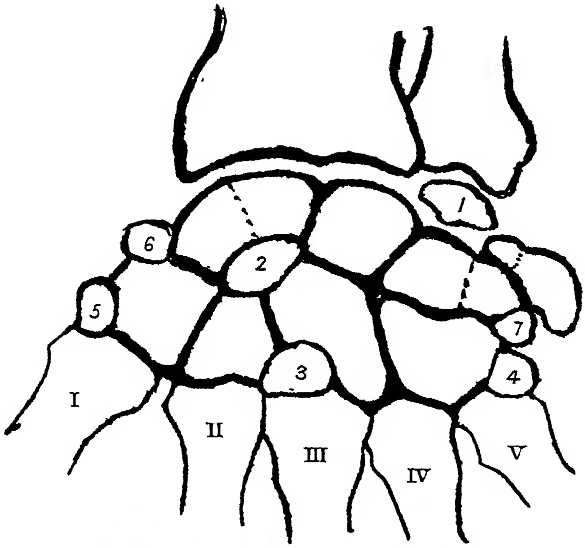
All of those will not be recognisable by X rays, and to differentiate them special positions may be necessary, but the following have been reported as so recognised:—

Os centrale, between scaphoid and os magnum, No. 2 opposite.
Os triangulare, between ulna and pyramidal, No. 1 opposite.
Os vesalianum, at base of 5th metacarpal, No. 4 opposite, and a *bipartite scaphoid.*

The appearance of a bipartite scaphoid may be due to two centres of ossification remaining separate, but many cases quoted as such by anatomists are doubtless due to former injuries causing fracture of the scaphoid, of which the fragments have failed to unite.

Spine.—With the patient on his back, the tube centred over the region to be inspected, and the plate placed under that region, a view of a number of vertebræ may be obtained, the number so included with serviceable accuracy in a single plate depending upon the distance at which the tube is set. A greater distance of the tube serves to reduce the distortion of the marginal parts (due to divergence of radiation, as explained on page 147), but it is practically impossible with the usual apparatus to get on one plate a view of more than five vertebræ which will be of any value in diagnosis. Hence, for a complete

Dorsal aspect.



Plantar aspect.

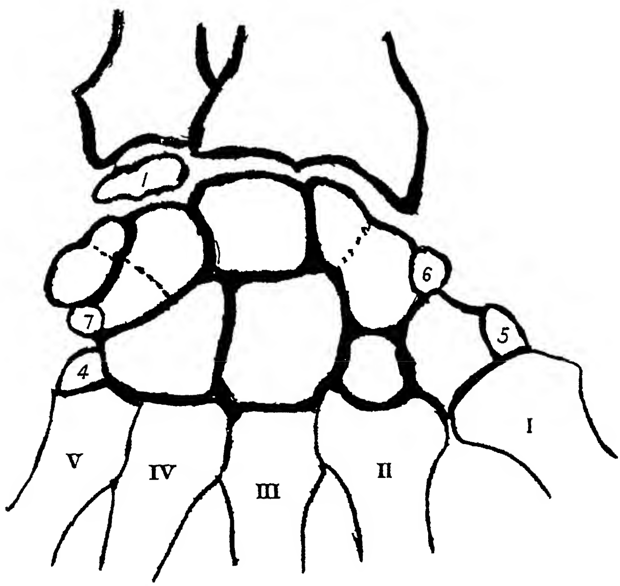


Fig. 198.—Bones of Carpus—Normal and Extra.

1. Os triangulare.
2. Os centrale.
3. Os styloideum.
4. Os vesalianum.
5. Os paratrapezium.
6. Os radiale externum.
7. Os ulnare externum.

Scaphoid (or *naviculare*) has been frequently described as *bipartite*).

Pyramidal (or *triquetrum*)
Pisiform } may also appear in two parts.

Plate III.

Fig. 199.—SPINE, ANTERO-POSTERIOR, RADIOGRAPHED WITH A POTTER-BUCKY DIAPHRAGM.

Fig. 200.—SPINE, LATERAL, RADIOGRAPHED WITH A POTTER-BUCKY DIAPHRAGM.

Fig. 201.—FRACTURE-DISLOCATION OF CERVICAL VERTEBRÆ.

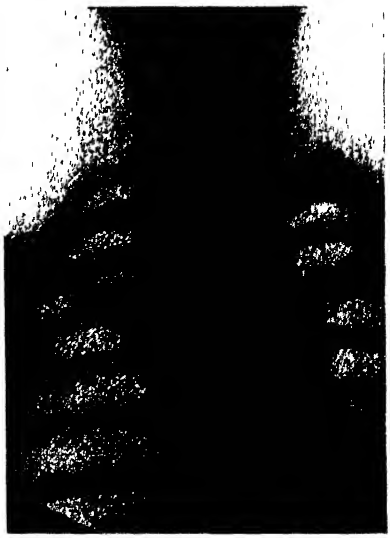


Fig. 202.—CERVICAL RIB.

Plate IV.

survey of the spine a series of plates should be exposed with the tube centred over successive sets of five vertebræ, and so that marginal vertebræ in one plate will appear in the centre of the next.

Thus fracture, dislocation, necrosis, or abscess may be revealed and located. In seeking the two latter a careful screen examination should be made of the whole length of the spine, or serial radiograms made, before expressing an opinion of their absence, since localising symptoms may give little or no true indication of the region to inspect. A *lateral* view may be most valuable in any of those conditions, and should always be made, but the observer must remember the distortion produced by the necessary distance of the plate from the vertebræ in this position.

A *Potter-Bucky diaphragm*, as described on page 150, is most useful in radiography of the spine; and, besides giving a clearer picture, this piece of apparatus permits the efficient inclusion in one plate of a larger number of vertebræ. Figs. 199 and 200 opposite are from radiograms so exposed.

The *cervical* vertebræ are more accessible than the lower regions of the spine, but special pains are necessary to secure inclusion of the seventh cervical in a lateral view. The head should be supported on blocks, so that the spine is straight, and if the plate be laid on top of those blocks the lower edge of the plate must be pressed well down on the clavicle while the arm is pulled down by the side as far as possible. Alternatively, the plate may be laid under the shoulder and the tube removed to a greater distance to minimise deformity. The longer exposure thus entailed will be no disadvantage if the head be steadily supported.

Fig. 201 shows the radiographic appearance of a *fracture dislocation* of the cervical vertebræ. An antero-posterior view of this region may be obtained by setting the tube opposite the widely-opened mouth, while the plate is placed on the back of the neck. The lateral view is more likely to reveal any damage, since displacement or angulation will usually be antero-posterior in direction in this region.

For views of the *lumbar* region the patient should lie with his knees drawn up, so as to minimise the forward curvature.

In this and the thoracic region displacement or angulation is likely to be lateral. For all views of the lower regions of the spine the bowels should previously be well cleared, otherwise interfering and confusing shadows will probably be superposed.

In examining a radiogram of the spine it must be remembered that occasionally in the transverse processes of the lumbar region there occur congenital clefts somewhat resembling a line of fracture. The latter is, however, more irregular, and the presence of callus usually serves to differentiate. *Fractures* of transverse or spinous processes or of laminæ are often unsuspected until revealed on a radiogram.

Figs. 265 and 266, on page 328, represent evident cases of tubercular disease of the spine with marked angulation, but it is in earlier cases, with less marked deformity, that the chief value of X-ray examination lies.

Normally a spine may shew *curves* in its length, but *angles*, as in Fig. 267, are indicative of injury or disease. In very young subjects, before ossification of vertebræ is far advanced, bone changes may not be detected, and appearance of abscess may be a first indication of disease as diagnosed by radiogram.

A method for location of *tumours* in the *spinal canal* is described on page 370.

Ribs.—The *posterior* ends of the ribs shew up well in radiograms exposed as for the spine, as in Figs. 199 and 265, but the *lateral* and *anterior* portions are not so easily recorded. The patient must be placed in position and so rotated that the seat of injury faces directly downwards, and the plate so placed that its centre is in close apposition to the suspected locality. Care must be taken to avoid superposition of the spine vertically over the plate, the patient being so tilted as to throw the dense shadow of the vertebræ to one side or the other.

Extra ribs may occur in the cervical or lumbar region, and, in the former situation, may give rise to symptoms demanding their removal. Their recognition by radiography may clear up an otherwise puzzling history of brachial neuritis, and search should always be made in such cases. An extra rib on one side, as in Fig. 202, is easily recognised by contrast with the other side, but a pair of cervical ribs may easily be mistaken for the first thoracic pair, so that the whole set must be enumerated. Other abnormalities may be detected, but should be recognised by correlation with reported anatomical variations.

Pelvis.—With the patient on his back and the tube below, the latter should be set by viewing the shadow on the screen, so that the sacro-coccygeal articulation lies at the centre of the circle made by the diaphragm. Fig. 203 reproduces diagramatically the radiographic appearance of a pelvis so exposed, and from this it may be seen that the shadow produced is a somewhat distorted image of the bony pelvis. In this instance the distortion is useful, since it throws the rami clear of the sacrum, and allows a fracture to be more readily observed.

To detect *fracture of the rami*, the plate (10 by 12 in.) should be so placed that the symphysis pubis is apposed to it about

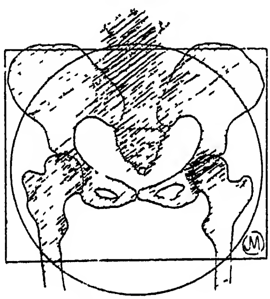


Fig. 203.—Position for Pelvis.

the junction of the middle and lower third of the plate's width.

With the tube set above the table, the patient must lie on his face with the plate under him for a view of the pubic region.

This is the most useful view for general purposes, but may be modified in special cases. Thus, when information is desired regarding the *sacro-iliac synchondroses*, the plate should be placed behind as for the spine.

To procure a view of the bladder, to aid the diagnosis of calculus, the method is described later (see page 504).

For *measurement* of the pelvic brim or inlet several methods have been devised, but none of those are very satisfactory.

The principle of *orthodiagraphy* might be applied with advantage to this problem, but has not so far been put into practical use.

See Fig. 456 on page 515 and attached note.

With a *Potter Bucky diaphragm* an inclusive view of the *pelvis and both hips* may be efficiently included in one view (as in Fig. 204), but each hip should further be investigated separately, as described in the succeeding section, if there is any suspicion of abnormality.

For inspection of the *sacro-iliac synchondroses* it is important that the tube should be carefully centred over the mid-line of the sacrum, so that the linear cartilage spaces on each side may be compared (see page 367).

Hip.—With the patient on his back, unless the nature of the lesion forbid, both legs should be extended, and the two feet tied together so as to maintain inward rotation of the limbs. This rotation brings the femur necks horizontal, thus

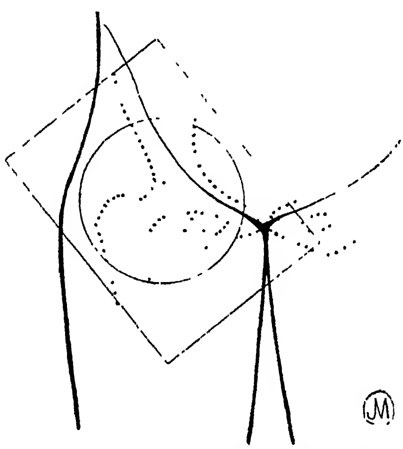


Fig. 205.—POSITION FOR HIP JOINT.

presenting their greatest length, and, along with the great trochanters, brings them closer to the plate in front.

If necessary for steadiness, the knees should also be tied together, and the feet supported in a central position by placing sand-bags or other heavy objects against them on either side. In a view of both hips on one plate, there is unavoidable distortion of each side, and for critical inspection a separate view of the suspected side is essential, except possibly in cases of very young children in whom the dimensions are diminutive

With the tube below, it should be set so that the circle of the diaphragm includes a view as shewn in Fig. 205, and the plate should be placed as shewn, over the front of the joint, with its long axis parallel to the fold of the groin, pressure being made upon it so as to bring the edge which lies on the

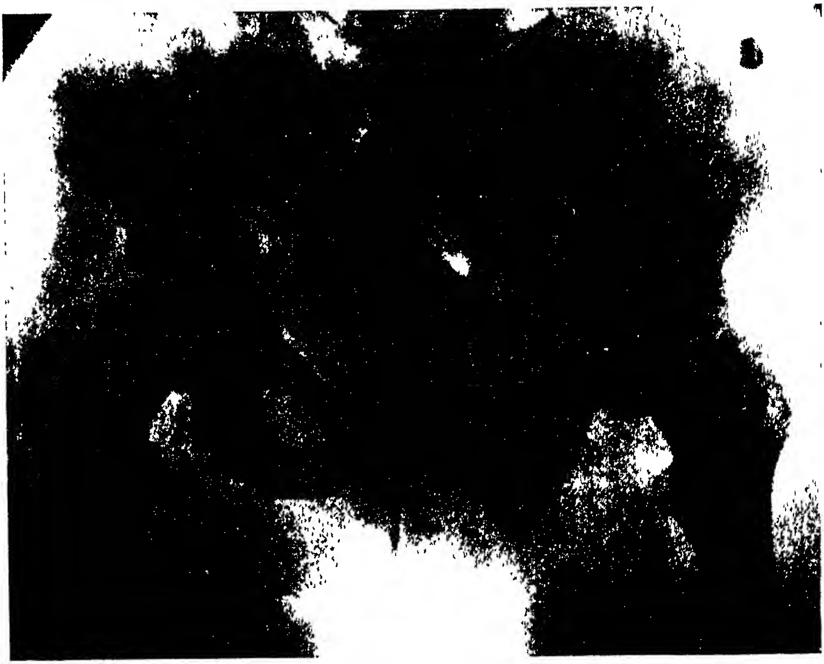


Fig. 204.—View of Pelvis and both Hips, taken with Potter-Bucky Diaphragm (Right Side Normal).

Fig. 206.—Hip-Joint in Normal Position.

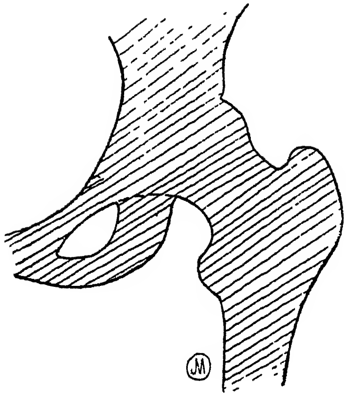


Fig. 207.—DIAGRAMATIC RADIOGRAM OF NORMAL HIP.

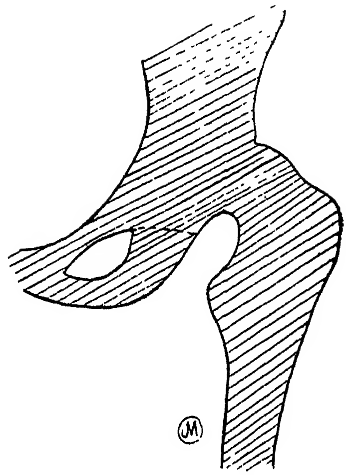


Fig. 208.—DIAGRAMATIC RADIOGRAM OF ABNORMAL HIP.

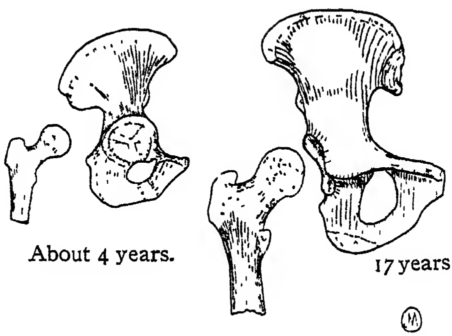


Fig 209.—CENTRES OF OSSIFICATION AND EPIPHYSES ABOUT HIP JOINT.

Pelvis is largely cartilaginous at birth, ossification proceeding from the three centres—**ilium, ischium,** and **pubis. About puberty** epiphyses form in the **ischial tuberosity,** the **anterior inferior spine** of the ilium, at the **symphysis pubis,** and in the **iliac crest.** These **unite** with the main bone about the twenty-fourth year.

Femur.—At birth the head and neck are wholly cartilaginous. In the **head** a centre appears in the first year, and unites about the nineteenth year to the neck, which ossifies from the shaft. In the **great trochanter** a centre appears in the fourth year, and unites to the shaft about the eighteenth year. In the **small trochanter** a centre appears in the fourteenth year, and unites to the shaft about the seventeenth year.

abdomen down nearly to the same horizontal plane as the other edge. A plate of "whole-plate" size ($8\frac{1}{2}$ by $6\frac{1}{2}$ in.) readily includes all that is required in a view of a hip joint, but for a more inclusive view a plate 10 by 12 in. may be used.

With the tube above the table, the plate should be placed under the buttock, and the tube set opposite the centre of the joint. This position has definite advantages, especially with children. The *centre of the joint* may be taken as lying under a point a finger's breadth below the middle of Poupart's ligament joining the anterior superior spine of the ilium and the pubis; a line drawn horizontally from the latter point crosses the lower part of the head. Where a combined view of two hips is desired, the plate should be set across both buttocks, and the tube set over the central point one or two inches above the pubis, the feet being meanwhile placed symmetrically with their inner sides touching, and the patellas facing directly forwards.

Fig. 206 shews the appearance of a normal joint exposed as directed above. The observer should become familiar with the appearance of the joint and head and neck of the femur while the leg is in various positions of abduction and rotation, as disease of the joint may make the normal position impossible.

For general purposes the view in Fig. 206 may be too limited, since it is important to include in the radiogram a clear view of the obturator foramen, the line of the upper border of that being made an important index in deciding the position of the head and neck of the femur, as described by Shenton ("Shenton's line").

From Fig. 207, which represents a normal hip joint, it may be seen that the lower border of the neck of the femur forms a continuous curve with the upper edge of the foramen. Any displacement of the upper end of the femur, due to fracture, dislocation, or disease, will, of course, disturb the relation so projected in shadow, and the lack of continuity of the parts of this curve will indicate the abnormality. In Fig. 208, which is from a case of tubercular disease of the joint, with absorption of bone, this altered relation may be noted. See also Fig. 307, on page 352.

The hip joint being a part of which it is rather difficult to obtain a view with clear differentiation, this plainly visible index is very useful, but the standard position of the limb must be carefully maintained.

Knee.—The position of the plate on this joint must be decided according to the information required, bearing in mind that the plate should be closely apposed to that aspect of which the most distinct view is desired. Thus, to secure an outline of the patella that part must be placed directly against the film, and for that reason the position with the patient lying face downwards and the tube above is the most useful standard position for general purposes. The tube should be set, as a rule, opposite the line of the joint, so as to send its central ray clear through between the articulating surfaces and produce on the radiogram a clear separating line in all positions.

Fig. 210 shews on one film an antero-posterior and a lateral view, the former having been made with the plate behind the joint while the leg was fully extended and the toes of the two feet placed together.

If set by the screen the tube should be moved to that position in which it shews the maximum width of clear space (cartilage) between the shadows (bone) of the femur and tibia. With the tube above the table, the level of the joint may be taken as just below the lower border of the patella, and the tube should be centred opposite that landmark. For a lateral view the same line should be taken, and the tube centred a little anterior to the point where it cuts the middle line of the femur condyles.

The frequent presence of a *sesamoid bone* in the external origin of the gastrocnemius muscle should be remembered in examining the knee joint; otherwise a loose body may be erroneously diagnosed.

The danger of this error was strikingly illustrated in the case of which the radiograms are reproduced in Fig. 211. The appearance of arthritic fringing on the small bone seen behind the condyles led the surgeon to doubt that it could be a sesamoid, and he had decided to open into the joint, but a demonstration on the screen of its movement with the gastrocnemius in flexing the knee placed the matter beyond doubt.

The figures opposite shew the change in position of the sesamoid in the two positions of the knee, and this method of differentiation should be borne in mind in similar cases (see also page 368).

Fig. 210.—Normal Knee Joint—Antero-Posterior and Lateral Views.

Fig. 211.—Sesamoid Bone in Origin of Gastrocnemius Muscle.

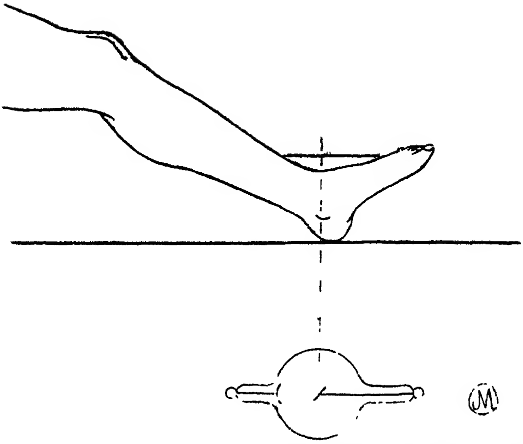


Fig. 213.—POSITION FOR ANKLE JOINT.

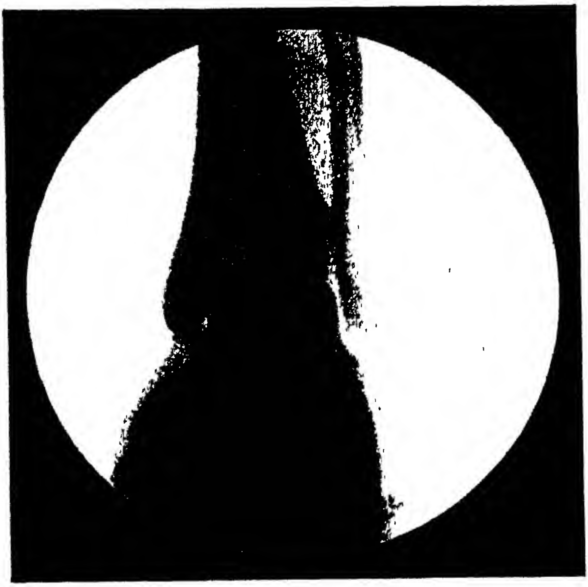


Fig. 214.—NORMAL ANKLE JOINT.

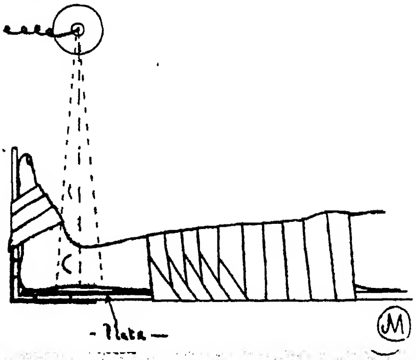


Fig. 215.—POSITION FOR ANKLE JOINT, WITH POSTERIOR SPLINT.

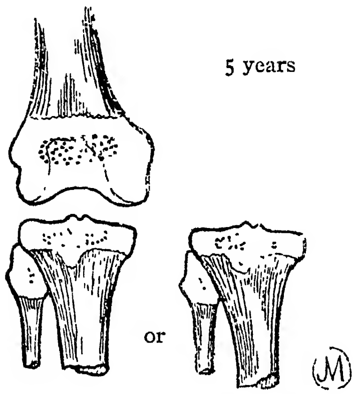


Fig. 212.--Centres of Ossification and Epiphyses about Knee Joint

Femur at birth has a small centre of ossification in the lower end, which unites to the shaft soon after the twentieth year.
Patella ossifies from a single centre, which appears during the third year, ossification being completed about the eighteenth year.
Tibia at birth has a small centre in its upper epiphysis, which unites to the shaft about the twenty-second year. The **tubercle** is occasionally formed from a **separate centre.**
Fibula at birth is cartilaginous at both ends. A centre appears in the head about the fourth year, and unites to the shaft about the twenty-fourth year.

Ankle and Foot.—Here there is a choice of position, which ought to be decided in a similar way to that for the knee. Of the joint-space the clearest view is obtained by placing the patient either sitting on cushions of suitable height, or kneeling upon his sound knee on the couch with the leg to be radiographed stretched out in front of him, and the heel resting on the level of the couch, as shewn in Fig. 213.

If the fluorescent screen be placed across the front of the ankle, and illuminated from the tube set vertically under the heel, the position of the foot may then be manipulated until on the screen is seen a shadow of the astragalus, with a clear space round the three sides of its articulation with the tibia and fibula, as seen in Fig. 214, which reproduces a view taken with the foot in this position. The clearest view will be obtained with the foot nearly at right angles to the leg, the shadow of the os calcis being thus prevented from obscuring the desired view. Slight internal rotation also contributes to a clearer view, bringing the fibula more nearly into the same plane as the tibia. Conversely, with the plate placed under the heel, the tube may be set directly above the central point between the malleoli and the exposure so made. (See also Figs. 176, 177, and 178, on page 258.)

In such a view a fracture of the astragalus or either malleolus may be readily detected; while, in addition, any separation of the tibia and fibula by tearing of the interosseous ligament may be observed in a way possible in no other position.

The region of the ankle joint is often made difficult to radiograph by the presence of iron in a *posterior splint*, which it may be undesirable to remove.

If a view from either side be unsatisfactory, the bandages may be loosened from the lower part of the splint until it is possible to push a plate gently in between the limb and the splint, as shewn in Fig. 215. Then, setting the tube in a suitable position above the limb, the exposure may be made. In a similar manner, an antero-posterior view might be obtained of the foot or of any higher part of the leg without removing the splint.

A *lateral* view from either side also shews the ankle joint fairly clearly and gives in addition a clearer view of the tarsal bones than is possible in the antero-posterior position. Fig. 216 shews such a view taken with the plate on the external aspect of the foot. For a view of the metatarsals and phalanges and of the tarso-metatarsal joint, the foot should be set flat on a plate and the tube centred over the latter joint. The individual cuneiform bones can never be shewn clearly because of their wedge shape. The internal of the three is overlapped by the shadow of the first metatarsal, which overlapping may simulate a fracture. Fig. 217 shews a convenient view taken with the inner aspect of the foot in contact with the plate and the tube set over the joint between the two rows of tarsal bones, those being thus shewn separate, and the cuboid with the two outer metatarsals being specially well shewn.

Variations and Extra Ossicles in Ankle.—Whilst variations are not so common amongst the tarsal bones as amongst the carpal, there are a number of "extra bones" found, those being produced from separate centres of ossification not normally present.

If the abnormal appearance of such on a radiogram is not recognised as due to this source, a mistaken diagnosis of fracture is very probable.

Those extra ossicles are discussed by Dr. Thurstan Holland in the "Archives of Radiology and Electrotherapy" for September, 1921, and, as listed in Quain's "Anatomy" (1915),

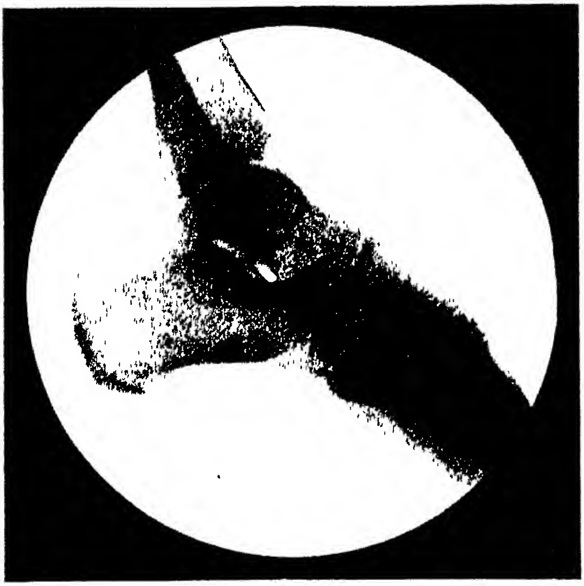


Fig. 216.—Lateral View of Ankle and Tarsus.

Fig. 217.—Semi-lateral View of Foot.

Plate IX.

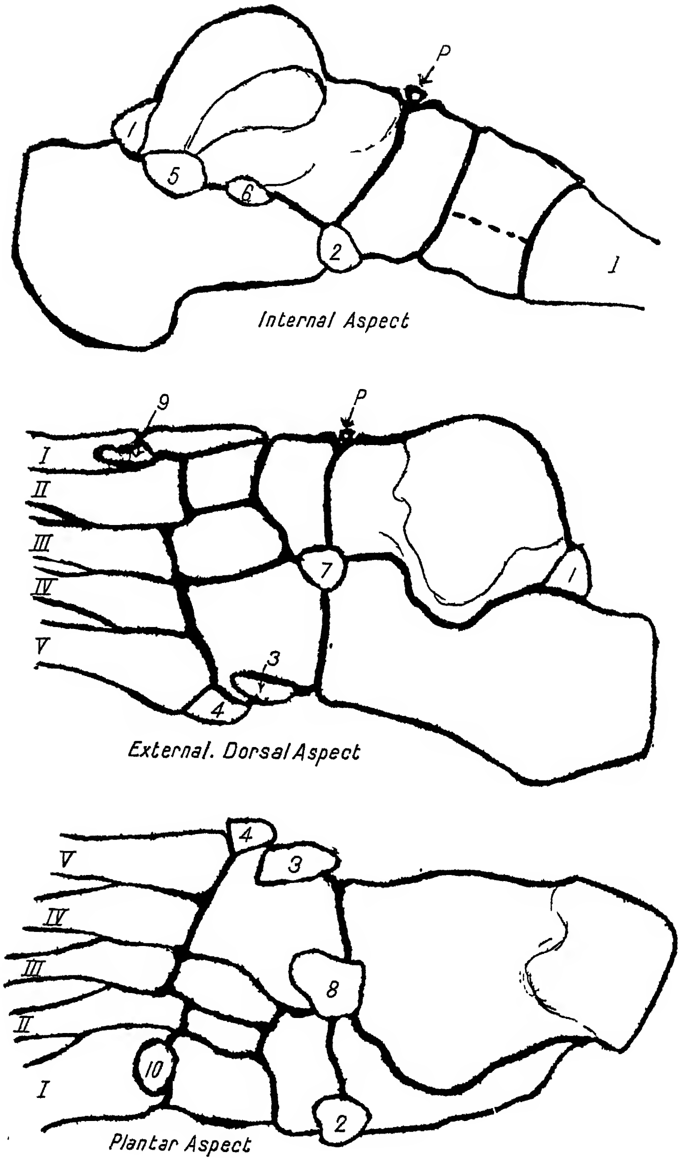


Fig. 218.—Extra Ossicles of Tarsus (see p. 290.)

Plate X.

with reference to diagrams, Fig. 218, they are :—

1. **Os trigonum**
2. **Tibiale externum**
3. **Sesamum peronæum** (in tendon of peronæus longus)
4. **Os vesalianum**

commonly detected in radiograms.

5. *Talus accessorius.*
6. *Os sustentaculum.*
7. *Calcaneus secundarius.*
8. *Cuboidus secundarius.*
9. *Os intermetatarseum.*
10. *Pars peronœa metatarsalis I.*

Internal cuneiform may appear in two parts; **cuboid** has also been so described.

An additional *dorsal astragalo-scaphoid ossicle* (P in opposite figure) is described by Pirie in " Archives of Radiology and Electrotherapy " for August, 1919.

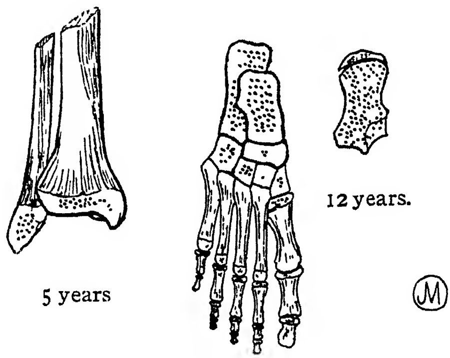


Fig. 219.—Centres of Ossification and Epiphyses about Ankle Joint.

Tibia at birth is cartilaginous at its lower end, in which a single centre appears in the second year, and unites to the shaft about the nineteenth year.

Fibula at birth is also cartilaginous in its lower end. A centre appears in the second year and unites about the twenty-first year.

Tarsal bones ossify each from one centre; the os calcis has in addition an epiphysis posteriorly. The centre of the **os calcis** and the centre of the **astragalus** are apparent at birth, the centre of the **cuboid** appears about time of birth, of the **external cuneiform** in the first year, of the **internal cuneiform** in the third year, of the **middle cuneiform** in the fourth year, of the **navicular** in the fourth or fifth year; the **epiphysis** of the **os calcis** appears about the tenth year, and unites to the main bone about the sixteenth year. The **metatarsals and phalanges** have each one epiphysis, which begins to ossify from the third to the eighth year, and which unites to the shaft between the eighteenth and the twenty-first year. The four **outer metatarsals** have the epiphysis at the distal extremity; the **first metatarsal** and the **phalanges** at the **proximal**. The first metatarsal may have a distal epiphysis in addition, and the fifth metatarsal may have a second epiphysis in its tuberosity.

Skull.—Of the skull radiography is not very satisfactory, because of the thinness of its component bones and the unavoidable superposition of the opposite side. Much interesting work has been done in radiography of the *antra* and *accessory sinuses*, but the value of this lies entirely in its interpretation, in which a regional specialist has obvious advantages. Interesting and valuable observations are recorded in various monographs, and those should be consulted by anyone wishing to do *special* work in these regions. The fluorescent screen is of no practical use in this region, and the methods of radiography are purely regional in detail and technique, *but a few general principles must be borne in mind in all cases.*

First, it must be carefully considered how to get the *part* under enquiry *as near* to the sensitive *film* as possible, so as to minimise distortion and also lessen the interference of the parts of the skull nearer the X-ray tube. Secondly, the *direction of the central ray* must always be noted and the tube carefully centred opposite the part of which an image is desired.

Towards those ends it is essential to bear in mind the *regional anatomy* of the skull, and this may usefully be recalled by the two opposite figures—the upper (Fig. 220) being a medial longitudinal vertical section of a skull, and the lower (Fig. 221) a transverse horizontal section through the nasal cavity and adjoining parts. Normal appearances produced by *sutures* and the *channels of blood vessels* should be carefully studied, so as to differentiate them from fractures.

For the purpose of comparing the appearances of the various antra and *sinuses* under suspected conditions with the normal appearance of the same structures, it is essential that the conditions of exposure be strictly similar, and to secure this exactitude various methods have been suggested.

Supports for the head with clamps attached to a *special chair*, on which the patient sits, is probably the most convenient and precise arrangement for special work, but similar views may be obtained with the patient *recumbent* and with the head supported and steadied by sand-bags or by special supports and clamps.

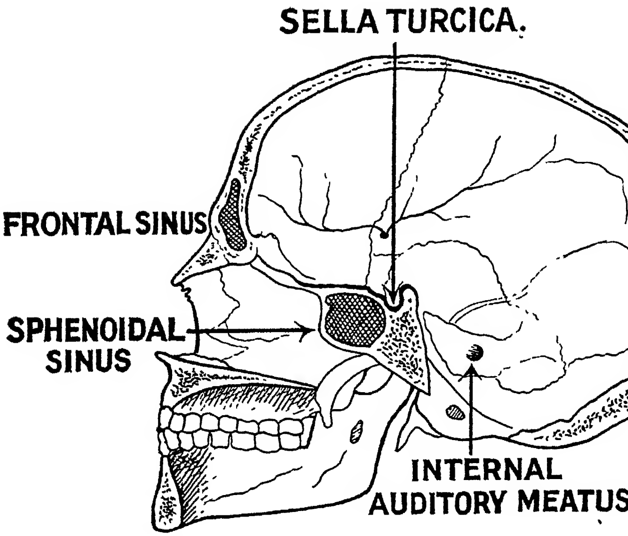


FIG. 220.—MEDIAN VERTICAL SECTION OF SKULL.

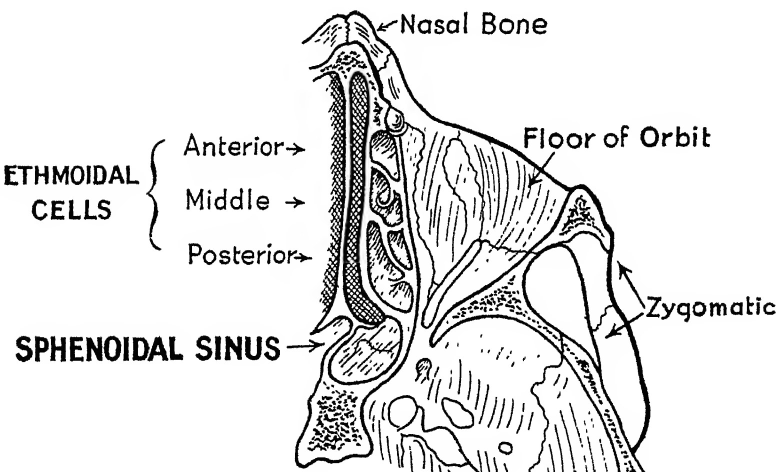


Fig. 221.—HORIZONTAL SECTION OF SKULL.

Plate XI.

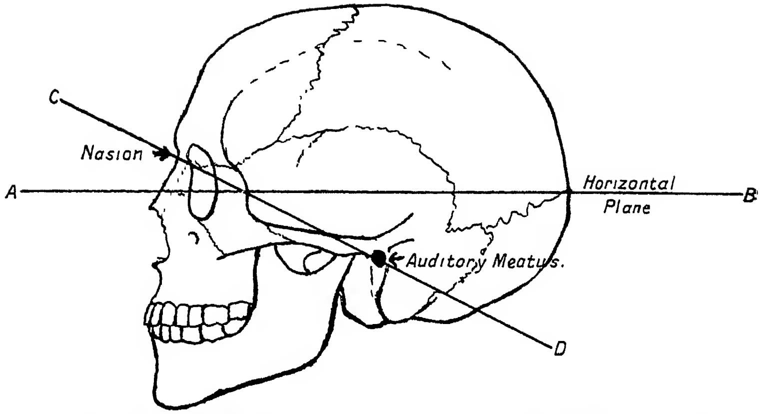


Fig. 223.—SKULL, SHEWING HORIZONTAL AND NASO-MEATAL PLANE.

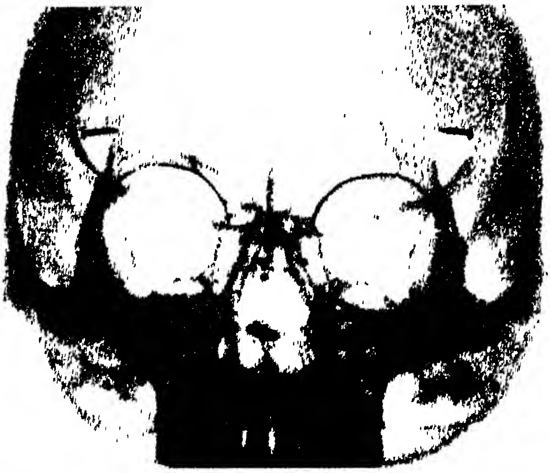


Fig. 224.—POSTERIOR-ANTERIOR RADIOGRAM OF SKULL.

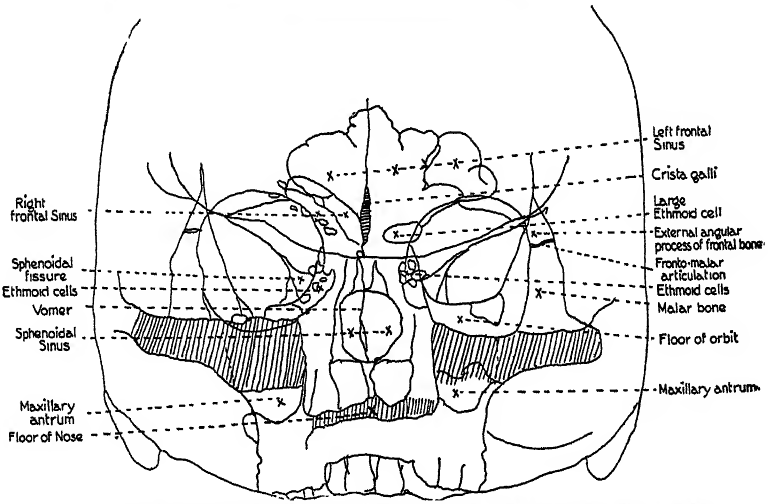
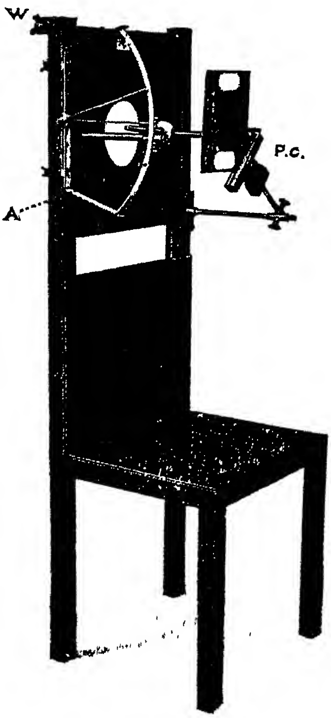


Fig. 225.—DIAGRAM OF PARTS SHEWN IN FIG. 224.

Fig. 222 shews such a chair, devised by Dr. Martin Berry, having attached to one side an "*angulometer*," by which the head may be set as desired, whilst the central ray from an X-ray tube set behind the chair passes horizontally through the centre of the hole in the back of the chair, into which hole fits the occiput of the patient.

Fig. 222A shews other fittings to the chair by which the head



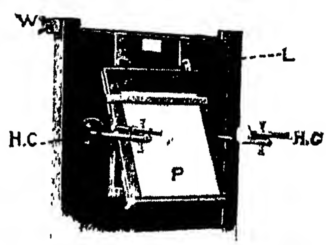


Fig. 222A.

Fig. 222.—Chair for Radiography of Skull.

may be clamped for lateral views, or, as in the figure, for oblique views of the jaw; but the principal feature of the chair is concerned with postero-anterior views. For such views two planes are conceived as passing longitudinally through the skull, as represented by the lines A B and C D in Fig. 223. A B is a plane, normally horizontal, which passes 1 in. below the naso-frontal articulation marked "*nasion*"; C D passes through the nasion and the external auditory meatus.

The position of the head is adjusted by observation of the latter plane, with its two prominent landmarks, the best position for viewing various structures having been previously ascertained by experiment and noted for reproduction in terms of the angle made by that plane with the horizontal.

The head is first placed in position, and the back of the chair adjusted till the occiput rests comfortably in the circular aperture, and the angulometer is set so that the fixed horizontal arm corresponds to plane A B, one inch below the nasion. The movable arm of the angulometer is then set to the pre-determined angle and the patient's head flexed or extended until the plane C D—the naso-meatal plane—corresponds to the movable arm. The tube is set so that its central ray corresponds to the horizontal fixed arm; thus its angle to the naso-meatal plane is fixed as desired, and the plate is secured in an adjustable holder, P C in Fig. 222.

For general views, and for a good view of the sphenoidal sinus, an angle of 25° is recommended—such a view is reproduced in Fig. 224 and annotated in the diagram in Fig. 225.

For examination of the upper portions of the face—ethmoidal region and roof of orbit—a larger angle is desirable, whilst for the lower parts, particularly the lower part of the maxillary antra, a smaller angle serves better.

Although this method may not be generally adopted, it serves to indicate the points to be observed in such work.

For *lateral views*, a definite axis should be decided upon for comparative views, or, if a particular site is indicated for inspection, relative positions must be chosen on the principles noted at the beginning of this section.

The *sella turcica*, apart from injuries, is the usual subject for enquiry, and the position for correct radiography of that region may well be taken as the standard position for lateral views; a resultant radiogram is reproduced in Fig. 226. The axis for the central ray should pass through a point on either side of the skull, one finger's breadth above the mid-point between the external orbital margin and the external auditory meatus. To set the tube accurately in this axis, the director shewn in Fig. 181, on page 264, may be found most useful. Stereoscopic views should be taken whenever possible.

For a *vertical view*, in order to inspect the sphenoidal sinuses and the zygomatic arches, the patient should sit by the edge of a table on which rests the sensitive plate, and his chin should be thrust as far forward as possible across, and in contact with, the plate. The tube should then be set centrally above his head, with the focal spot vertically above a point 2 cm. in front of the external auditory meatus. Such a view is shewn in Fig. 227.

Fig. 226.—LATERAL VIEW OF SKULL, SHEWING SELLA TURCICA.

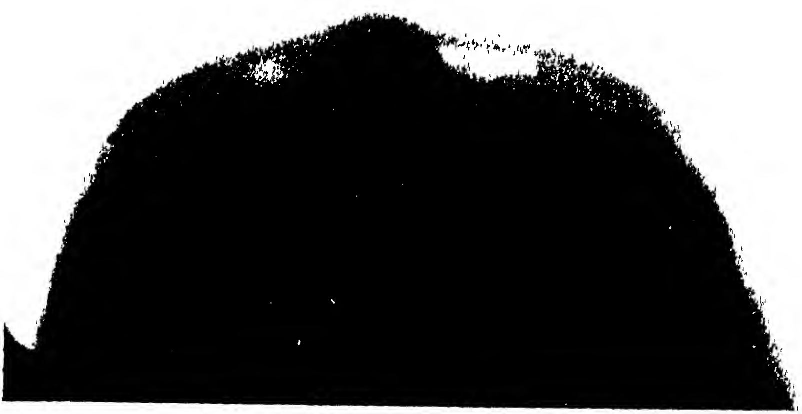
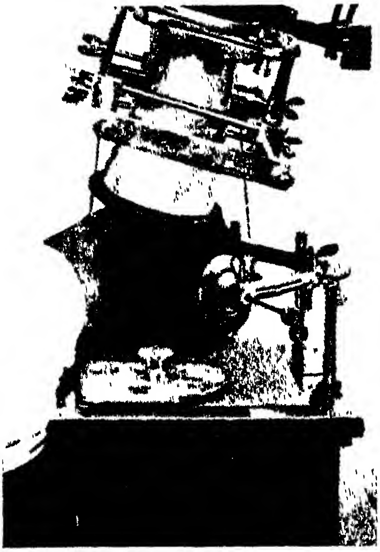


Fig. 227.—VIEW OF SKULL WITH TUBE VERTICALLY ABOVE, SHOWING SPHENOIDAL SINUSES.

Plate XIII.



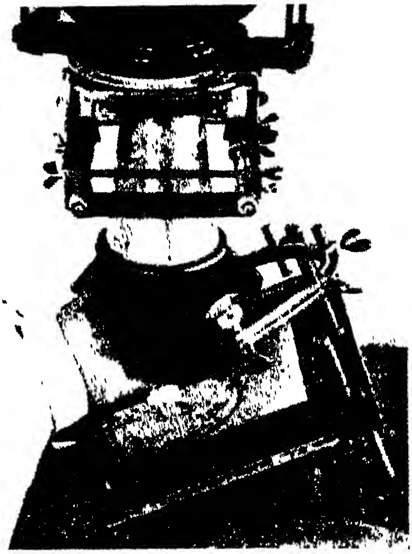


Fig. 228. Fig. 229.

SETTINGS OF TUBE AND PLATE FOR RIGHT MASTOID.

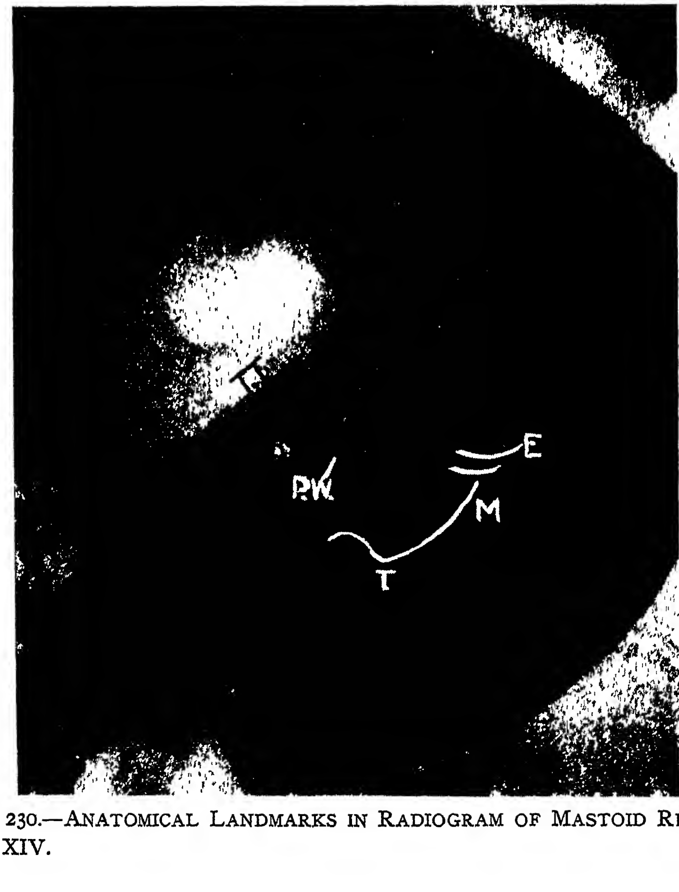


Fig. 230.—ANATOMICAL LANDMARKS IN RADIOGRAM OF MASTOID REGION.

Plate XIV.

Mastoid Antra.—Where a bilateral view can be secured in one exposure, the comparison of the two sides, upon which diagnosis depends, may be readily made. In the case of the mastoids, however, such a combined view of the two sides cannot efficiently be secured, and a separate exposure is here required for each side. The view desired is one with the plate placed against the external ear of the side to be recorded, and the head and tube must be set relatively so that the opposite side will cast no interfering shadow. Care must be taken that a precisely similar setting is made for both sides, so that comparison may be reliable. This region is dealt with exhaustively by Dr. Law in the first of the splendid monographs, edited by Dr. Case as "Annals of Roentgenology," and from that publication the description of the technique is condensed.

The appearances produced on a plate are correlated with the anatomical features in Fig. 230, the structures indicated being as follows:—

T.B.	Upper limit of squamous portion of temporal bone.	E.	Vein in mastoid foramen.
P.	Pinna of ear.	M.	Limit of mastoid process.
T.T.	Tegmen tympani.	T.	Tip of mastoid process.
S.	Anterior wall of groove for lateral sinus	M.A.	Mastoid antrum.
K.	Knee of lateral sinus.	E.M.	External auditory meatus.
P.W.	Posterior wall of auditory canal.	I.M.	Internal auditory meatus.
		G.	Glenoid fossa.
		C.O.	Candyle of jaw.

The two mastoids are recorded by successive exposures on adjoining areas on one plate, each area being in rotation protected by a piece of lead of appropriate shape. It is important that each image be immediately and plainly marked R or L, to indicate which side was in contact with the plate at the time of its production, as otherwise confusion may readily arise—particularly where double-sided films may be used.

With the pinna of the ear turned forward, the side of the head is placed flat on the plate, with the external meatus over the centre of the unprotected area, and so that the sagittal plane of the head is parallel to the plate. Thus set, the head should be clamped for steadiness in this position. The tube should now be set above the opposite side of the head, so that the central ray passes to the external meatus to be recorded through a point 2 in. (5 cm.) above and 5 in. (2 cm.) behind the external auditory meatus of the opposite, and upward, side.

Thus set, the central ray will make an angle with the vertical of 15 degrees towards the feet and 15 degrees towards the face. This may be arranged by giving a double tilt to the

tube box, or the plate may be laid on a plane set at the required angles and the tube box kept vertical.

The former arrangement is shewn in Fig. 228; and in Fig. 229 is shewn a support tilted to secure one of the angles of inclination whilst the tube is tilted to secure the other. Five seconds is quoted as a proper exposure with 40 ma. through a tube of 5½ in. alternative spark-gap.

The structures of the mastoid region in different individuals shew considerable variation in structure, but, fortunately for diagnosis of alterations due to disease, both sides in any individual are usually of the same type, so that comparison of the two is, as a rule, reliable. Considerable topical knowledge and experience may be necessary to be able to ascribe definite causes for the alterations noted, but the appearances are readily recognised in radiograms carefully produced.

Presence of inflammatory fluid in the cells is marked by a blurring of the normal appearance, varying from a faint haze to a complete obliteration of all outlines. Bone softening will further obscure the normal outlines, and later, bone destruction will produce increase of transradiancy with complete loss of structure.

Fig. 231 reproduces a view of two mastoids exposed as described above.

In the case illustrated there was present a tumour of the fifth nerve, causing erosion of the walls of the canal containing it, as shewn by the small transradiant area seen in the centre of the right hand radiogram.

L. Fig. 231.—DOUBLE VIEW OF MASTOIDS. R.

Plate XV.

Fig. 235.—UPPER JAW AND PALATE.

Fig. 236.—LOWER JAW WITH CALCULUS IN WHARTON'S DUCT.

Views in Figs. 235 and 236 taken on quarter-plate placed horizontally in mouth.

Plate XVI.

Jaws and Teeth.—In *radiography* of the jaws and teeth, as in other parts of the skull, the difficulty of *superposition* of the two sides is encountered. Here, however, the difficulty may usually be got over by special arrangement of the X-ray tube relative to the part to be exposed, the central ray being directed to avoid that side of the jaw nearest to the tube. To a radiographer who has considered and understood the elementary principles, discussed in earlier sections, for the avoidance of distortion, this region need present no serious difficulty, but its special conformation must be remembered and appropriate modifications made in the details of exposure. *Diagnosis* of conditions revealed in such a radiogram must be left mainly to the dentist, with his intimate knowledge of the anatomy and pathology of the parts involved, but he must understand the correlation of radiographic appearances, and he may be gravely

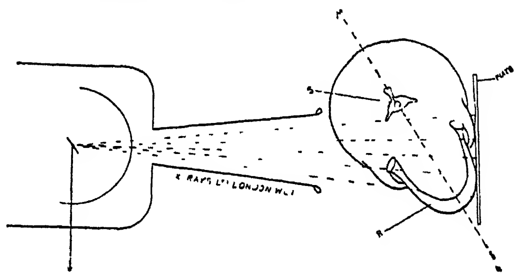


Fig. 232.—POSITION FOR ARTICULATION AND TEETH—MOLAR AND CANINE.

misled unless those appearances are produced by a carefully considered technique.

Two methods of exposure may be employed: (1) by use of plates or films placed *outside* against the skin covering the part to be exposed; or (2) by use of small specially prepared films placed *inside* the mouth in contact with the teeth or part in question

(1) *Extra-oral plates or films* give a more general view, suitable for detection of *fracture* or *disease* of a *jaw*, or for *preliminary location* of suspected disease about the roots of teeth.

(*a*) For a view of the *ascending ramus* and *articulation* of the lower jaw along with the upper and lower jaws with the teeth from the last *molar to the canines*, the exposure cassette should be pressed against the cheek of that side of which a view is desired, and the X-ray tube should be set above and slightly behind the opposite shoulder, so that its central ray will pass between the cervical spine and the ascending ramus of the nearer side. Fig. 232 represents diagramatically the position.

(*b*) If detail of the ramus and articulation be more particularly desired, the cassette should be more closely compressed against the pinna of the ear. (*c*) Conversely, if detail of the teeth be more important, the forward segment of the plate should be pressed against the side of the nose, so as to deflect it as far as possible. This latter view should shew efficiently

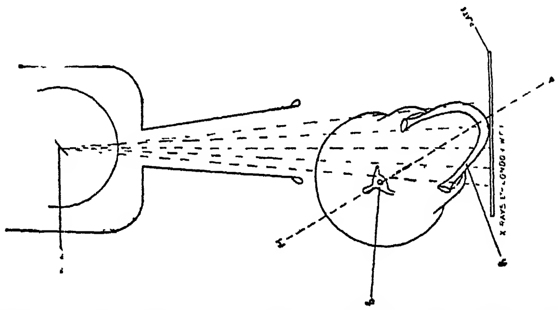


Fig. 233.—POSITION FOR TEETH—CANINE AND INCISORS.

all the teeth from the canines forward, as indicated in the diagram in Fig. 233.

(*d*) For the *lower jaw* alone the tube may be set opposite the shoulder, and the rays directed upwards so as to pass through the soft parts of the front of the neck and under the obstruction of the nearer side of the jaw, whilst a small plate is pressed closely against the outside of the part of which detail is required.

(*e*) For a view of the *median* part of *both* jaws with the *incisor*

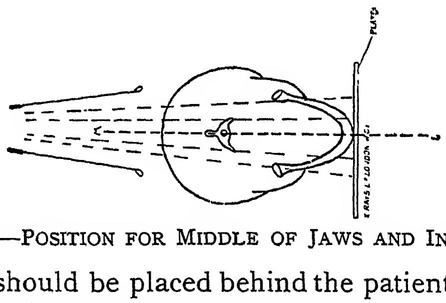


Fig. 234.—POSITION FOR MIDDLE OF JAWS AND INCISORS.

teeth, the tube should be placed behind the patient and the plate pressed against the chin and nose, the rays then passing as in Fig. 234.

A shadow of the cervical vertebræ will here inevitably be superimposed on the desired view, but at so great a distance from the plate the shadow will be a diffuse one, especially if the tube be placed close up to the neck.

In interpreting detail of the radiogram thus produced, however, the presence of the vertebral shadow must be remembered.

(*f*) Other views of the *median* part of *either* jaw separately may be obtained by placing a plate or film horizontally in the mouth, and passing it as far back as possible between the upper and lower teeth, which are then closed upon it.

A flexible film is commonly used for this purpose, and may be more comfortable for the patient, but, as pointed out by Dr. Gilbert Scott (in "Archives of Radiology and Electrotherapy" for September, 1920), a quarter-plate may be so used and has the advantage of rigidity.

The *roof* or *floor* of the mouth may be investigated by this method, along with the upper or lower jaw and incisor teeth, the sensitive side of the film or plate being turned upwards or downwards as required, and the X-ray tube set accordingly.

For the *upper jaw*, the tube should be set above the level of the top of the head, and tilted so that its central ray passes in front of the nose in a direction perpendicular to a line bisecting the angle between the upper teeth and the sensitive plate. This angle, as noted later and illustrated in Fig. 237, will minimise the distortion due to the lack of parallelism between the plate and the teeth, so far as the length of the latter is concerned, but a distortion in width is inevitable, the roots appearing disproportionately broad on account of their greater distance from the plate.

The *hard palate alone* may be seen better in a vertical view, as described for the skull on page 298.

For the *lower jaw* the head should be bent well back, and the tube set about the level of the diaphragm, and tilted so that its central ray is again perpendicular to the line bisecting the angle between plate and teeth. Figs. 235 and 236 shew views thus obtained of the upper and lower jaws, the latter shewing a calculus in Wharton's duct.

(2) *Intra-oral films* avoid the superposition of the opposite side, the film being placed close against the lingual side of the teeth and the adjoining gum, whilst the X-ray tube is set opposite the same side at a distance of 10 to 20 in.

Those "*dental films*," about $1\frac{1}{2}$ in. by 1 in. in size, are obtained ready for use, being wrapped in light-proof and waterproof coverings. Placed inside the mouth in the proper position, as above, the film must be held steadily in position, either by the patient's finger or thumb or by means of a special holder, of which several types are in use.

In the lower jaw, if the inner end of the film be well pressed down against the gum, the teeth and film may be considered as nearly parallel, and the setting of the tube may be made with its central ray perpendicular to the depth of the jaw, or but slightly below that level. In the upper jaw, however, the angle of the hard palate with the teeth interferes materially

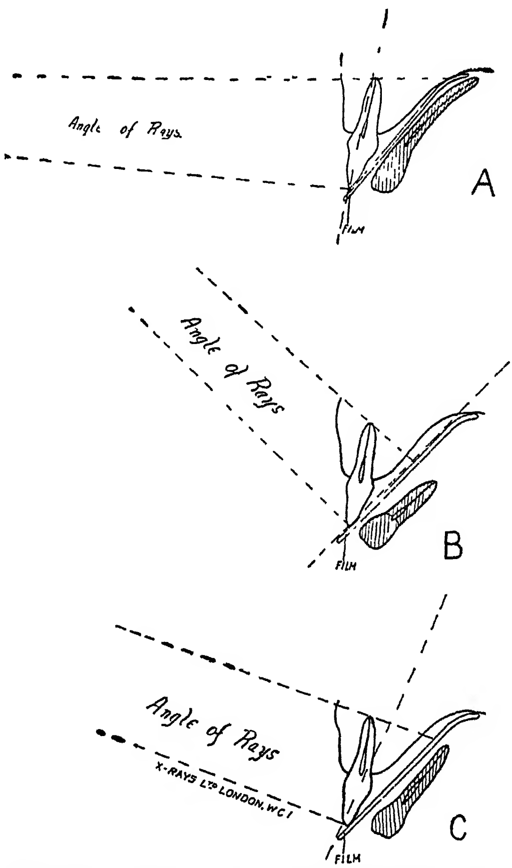


Fig. 237.—Setting of Tube for Upper Jaw.

with the setting of the film, and the setting of the tube must be specially arranged to minimise the consequent distortion.

This has already been referred to in discussing an inclusive view of the roof of the mouth, but Fig. 237 should make clear the relative points.

In position A the tube is set so that the central ray is *at right angles* to the plane of the *tooth*, with a resultant *lengthening* of its image on the inclined film.

In position B the central ray is at *right angles* to the plane of the *film*, with a resultant *fore-shortening* of the image of the tooth.

In position C a *compromise* is effected, and the tube set in a mid-way position, so that the central ray is at right angles to a line bisecting the angle of inclination between the tooth and film. The distortion in length is thus minimised, but a disproportionate width of the roots as compared with the crowns of the teeth is inevitable, and must be borne in mind in interpreting the appearances on the developed film.

By means of those films radiograms of specified teeth may be readily made, or a series may be produced of the whole set of teeth. This will require five or six films for each jaw, neighbouring films overlapping so as to facilitate identification and to obviate any gap in the series.

The conditions in which a dentist may seek the aid of radiology are many and varied. *Unerupted* teeth, *retained* temporary teeth, *impaction* and *irregularity* are obvious conditions of which a radiographic view will shew positive evidence. As a guide in regulation, and as a check in the process of *widening* and *filling* root canals, a series of radiograms may likewise be most valuable. In detection of pathological conditions radiography is proving more useful as dentists more clearly recognise its possibilities. *Pulp-stones*, as in Fig. 238, A, may be clearly revealed.

Alveolar abscess and *pyorrhœa* may in their early stages shew little or no radiographic evidence, but the later stages become plainly evident, and an X-ray examination may prove of critical value in deciding the presence or extent of either condition where local signs may otherwise be indecisive. The earliest appearance to be noted in such affections is change in the periodontal membrane, represented normally as a light line (in positive print) between a tooth and the surrounding bone of its alveolus. In *chronic periapical disease* this line early shews a *widening*, then rarefaction of alveolar bone is shewn by a *lighter area* at the apex of the root (Fig. 238, B). This rarefaction may extend and *detail* of bone structure be *obliterated* by presence of granulation tissue, at which stage the process may be referred to as "*granuloma*" (Fig. 238, C).

If more definite *suppuration* ensue, the periapical area becomes very transradiant, suggesting presence of an *abscess cavity*, into which the root of the tooth projects. The root of the tooth may shew an irregular margin, and the *outline* of the light area, if suppuration is active, will appear *eroded and ill-defined* (Fig. 238, D).

In position C a *compromise* is effected, and the tube set in a mid-way position, so that the central ray is at right angles to a line bisecting the angle of inclination between the tooth and film. The distortion in length is thus minimised, but a disproportionate width of the roots as compared with the crowns of the teeth is inevitable, and must be borne in mind in interpreting the appearances on the developed film.

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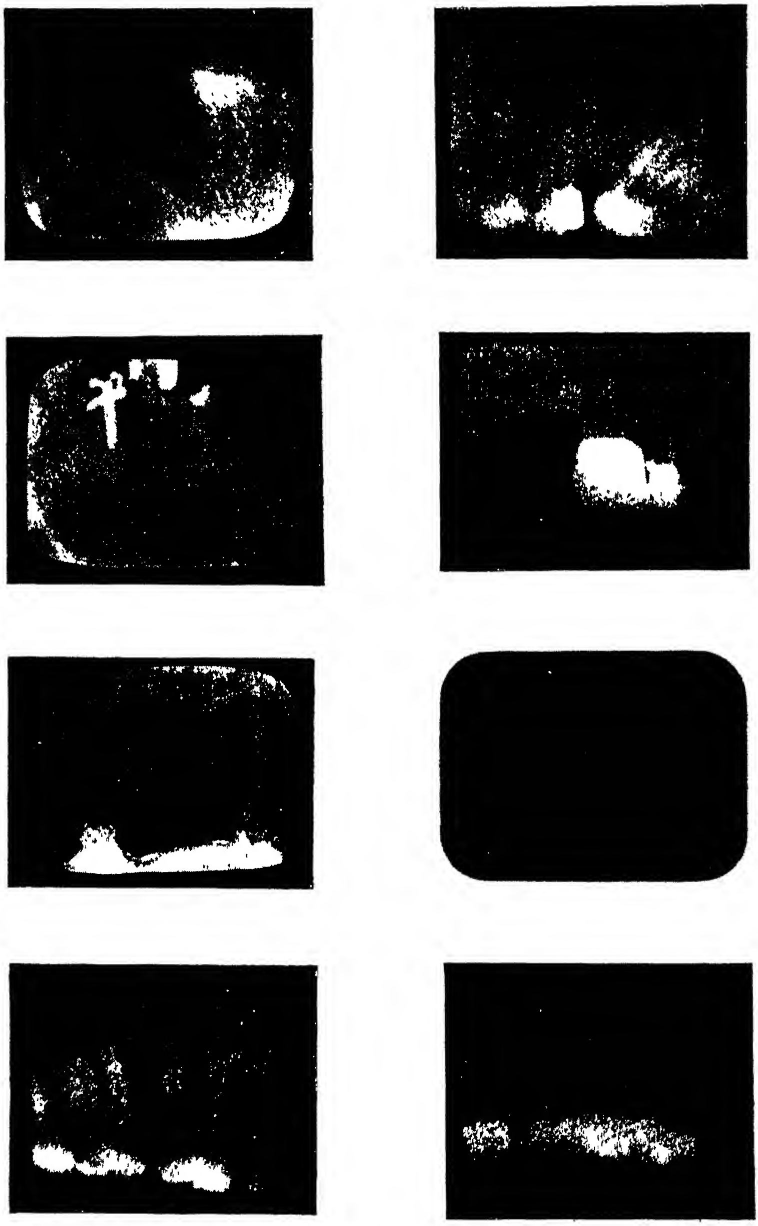
If a *less active* process results in a *cystic* formation at the apex, that will be marked by a similar light area bounded by a *definite margin*, with possibly a suggestion of lining membrane (Fig. 238, E).

In *pyorrhœa*, the *widening* of the light line representing the periodontal membrane is followed by *rarefaction and absorption* of interdental bone, shewn by the early *disappearance* of the apices of the *interdental spines* (Fig. 238, F), and later extension towards the apex of the tooth until the tooth appears surrounded by a transradiant tissue as if with *no bony support* (Fig. 238, G and H).

Those conditions are discussed by Dr. Woodroffe in the "Archives of Radiology and Electrotherapy" for December, 1920, and various other papers and monographs have been published on diagnosis of dental conditions. Those conditions may, however, be readily recognised in a radiogram by anyone familiar with them and their pathology if he takes the trouble also to acquire an understanding of the indications and interpretation of radiography in general.

Bone conditions may be detected in the jaw as in other bones by the appearances described in the later sections of this chapter.



A. B. C. D. E. F. G. H.

Fig. 238.—TYPICAL TOOTH CONDITIONS.

A. Pulp-stone.
B. Chronic alveolar abscess with osteo-sclerosis.
C. Granuloma.
D. Abscess with root absorption.
E. Cyst.
F. Pyorrhœa.
G. Pyorrhœal abscess.
H. Pyorrhœal abscess (from case with raised blood-pressure).

Plate XVII.

Fig. 239.—FRACTURE OF BOTH MALLEOLI..

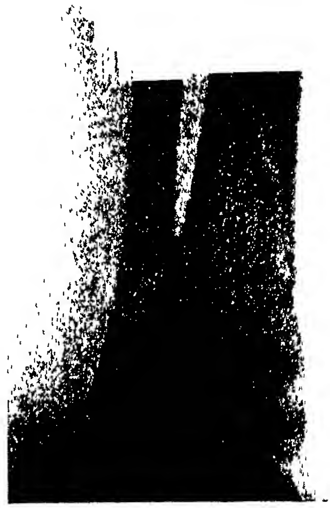


Fig. 240.—INCOMPLETE FRACTURE.

Fig. 242.—EPIPHYSIS (AT 10 YEARS) RESEMBLING FRACTURE.

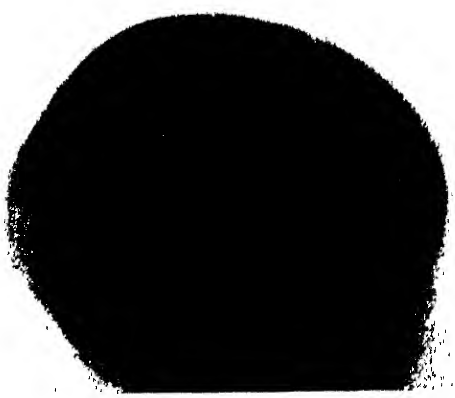


Plate XVIII.

Fig. 243.—CRANIAL FRACTURE.

(*e*) INJURIES TO BONES AND JOINTS.

Injuries to Bones and Joints are conditions for which the assistance of radiography is frequently sought; and in most cases, fortunately, the diagnosis is straightforward and simple if the correct procedure for each part be carefully followed.

The effect of an injury may not be immediately recognisable by X-ray examination, the earlier stages of disease conditions so initiated being unmarked by gross changes such as might be revealed in a radiogram. The later stages so revealed are considered under the heading of *Diseases* (page 318).

(i) **Fractures** are unfailingly revealed by a radiogram if due precautions be taken in the exposure. Much valuable information is thus obtained regarding the type and extent of a fracture, and equally, or more, valuable guidance in its treatment.

Surgeons are now well aware of the paramount importance of having a radiogram made of every fracture, however simple, and of the value of repeated observations of complicated cases.

Most fractures shew easily recognised appearances of displacement, as at the internal malleolus in Fig. 239, but partial fractures and fractures without displacement, as in Fig. 240, must be carefully looked for (see also Fig. 173 and accompanying note). Immobility of the part should always be ensured by use of sand-bags or other form of support. Each fracture should preferably be screened before being radiographed, so as to secure the most useful view of it, and so as to have the tube centred exactly opposite the seat of fracture. Otherwise the amount of displacement and consequent relative positions of the fragments may be falsely shewn and estimated.

This will be evident from a glance at the diagrams in Fig. 241, but to any reader who has appreciated previous remarks on the importance of correct centering of the tube and the incidence of the central ray this demonstration should be superfluous.

Fractures in the vicinity of joints present some difficulty in diagnosis even by X-ray examination; but in such cases the method is of the greatest value, since other methods often leave uncertain the differentiation between fracture, dislocation, or a combination of the two. Much depends upon choosing a

suitable position of the part during inspection or exposure, and upon a thorough knowledge of the normal appearances in each position of the part at the age of the subject under examination. A standard position should be fixed for each part and every exposure made with tube and part in that position, unless in exceptional cases. Thus comparison with other radiograms of the same part will be made possible and will be found most valuable. Standard positions for each joint are suggested, and appearances reproduced, in an earlier section of this chapter.

Various types of fracture, such as oblique, spiral, etc., will

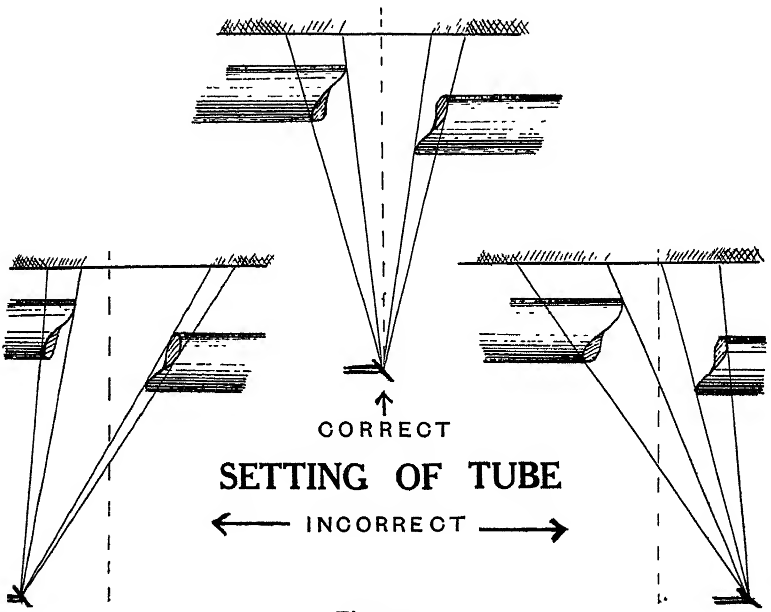


Fig. 241.

readily be recognised from inspection of radiograms taken from different aspects, but, as pointed out earlier, a single view should never be relied upon for precise information.

An ununited epiphysis may simulate a fracture (see Fig. 242), but consideration of the age of the patient should remind the observer of the possibility and obviate the error.

Cranial fractures (Fig. 243) may be difficult to recognise, appearing in a negative as thin black lines with ragged edges, which must be differentiated from the normal markings produced by suture lines, by blood vessels in the diploe, and by the arterial grooves on the inner surface of the skull. Those natural features all run a fairly definite course, and have smooth margins contrasting with the ragged darker lines of a fracture.

Fig. 244.—DISLOCATION.

Fig. 245.—FRACTURE NEAR JOINT.

Fig. 246.—PARTIAL DISLOCATION.

Fig. 247.—DISLOCATION COMPLICATED BY FRACTURE.

Plate XIX.

Fig. 248.—SEPARATION OF EPIPHYSIS.

Fig 249.—SEPARATION OF EPIPHYSIS.

Fig. 250.—"SLIPPED" EPIPHYSIS—IMPORTANCE OF TWO VIEWS.

Plate XX.

A depressed fracture may appear as a line of reduced density on the negative on account of its overlapping edges, whilst a depressed fracture of either table alone will appear as an area of irregularly altered density.

Fractures at the base are hard to demonstrate, and views from all aspects, including the vertical, must be searched most critically for evidence of slight displacement or of a fracture line.

Greenstick fractures in young bones will sometimes be difficult to record, on account of the unossified condition of the cartilaginous matrix, which is very transradiant and shews little or no contrast to surrounding structures. A very soft ray will be necessary to demonstrate the deviation of outline of the shaft of the bone concerned, but the abnormal position and relation of its ends will indicate the condition.

Repair will not be evident in a radiogram until deposition of calcium commences in the callus. This change, as shewn by denser appearances around the seat of fracture, occurs usually about the second or third week, and should be evident normally before the end of four weeks, the fracture line disappearing within four months. No evidence will be obtained, however, of the intervention of soft tissues between the fractured ends, thus interfering with union, nor will the amount of unossified callus or the presence of fibrous union be revealed in a radiogram.

(ii) **Dislocations** as a rule shew gross appearances readily diagnosed by ordinary means, as in Fig. 244. A complicating fracture near the joint involved may, however, require a radiogram to reveal its presence. This information is obviously of great importance and should be looked for in every case.

Differentiation between dislocation and a *fracture in the vicinity of a joint* (Fig. 245) may be impossible without a radiogram, and great care in the setting and centering of the tube over the joint is necessary to secure the most reliable view, which may have to be compared with views of normal joints exposed under the same standard conditions.

A *partial dislocation*, as shewn in Fig. 246, without a radiogram may be very hard to diagnose, as also a *fracture complicating a dislocation*, such as revealed in Fig. 247.

(iii) **Separation of an epiphysis** is another accompaniment of dislocation, for the detection of which a radiogram may be necessary. Since X-ray examination has become more common, many cases of supposed separation are found to be more truly fractures of the diaphysis close to the epiphyseal line. Figs. 248, 249, and 250 illustrate three cases of separated or "slipped" epiphysis. The latter incidentally illustrates the

(*f*) DISEASE OF BONE.

Disease of bone may in many cases be diagnosed from the changes produced in contour or structure, separately or combined. Similar changes and conditions may be produced by different diseases, hence for differential diagnosis the radiographic appearances must be considered in conjunction with allied signs and symptoms of the condition and its history. From a radiogram alone, however, many changes and conditions may be demonstrated without question, and the extent and course of the changes clearly noted, although the causative agency may not thus be revealed.

Broadly, but correctly, it may be said that two pathological processes only are registered, namely, destruction of bone and new bone formation. The former indicates an advancing lesion; the latter a retrogressive lesion, probably under control of regenerating activity. The relative degree of the two processes indicates the nature and stage of a lesion.

Rarefaction, as shewn in Figs. 251, 256, and 257, is evidenced by a lighter shadow at the part. This corresponds to a darker part in the negative, caused by the relatively greater amount of actinic rays permitted to pass through that part of the bone. Increased transradiancy is first due to absorption of lime salts, and later to actual absorption of bony tissue, and the appearances will vary accordingly.

Conversely, *sclerosis* is evidenced by a darker shadow on the positive print, corresponding to a lighter part on the negative, that part having been protected relatively by the denser tissue. In a similar way all gradations of shadow may be interpreted into physiological or pathological variations of structure, and by combined clinical and pathological knowledge these latter may be traced to their causative condition or disease.

The *contour* of the bone may be altered by absorption or by abnormal rate or direction of growth of bony tissue; or it may be affected by the intrusion of tumour formation (see Fig. 298, on page 347).

A progressive *absorption of lime salts*, and later *atrophy of bone structure*, appears in conditions of impaired nutrition of the

Fig. 251.—Rarefaction of Bone.

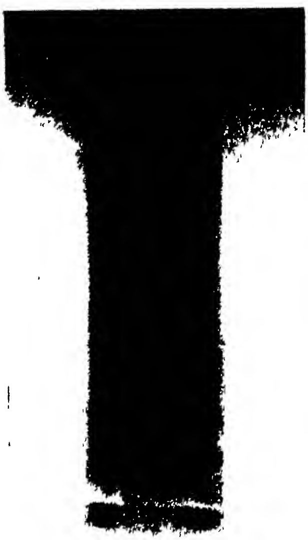


Fig. 252.—Ring Sequestrum.

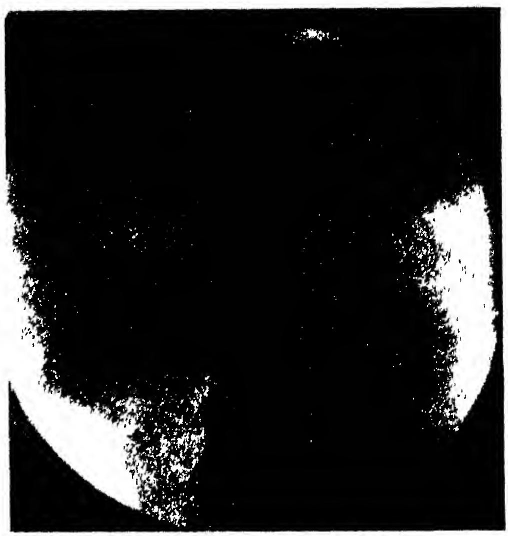


Fig. 253.—Calcification in Sinus leading to Diseased Vertebræ.

Plate XXI.

Fig. 254.—PERIOSTITIS.

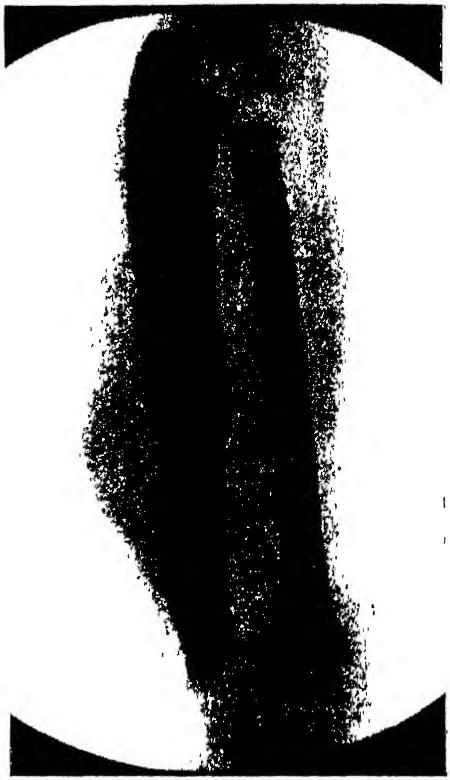


Fig. 255.—OSTEOPERIOSTITIS.

Fig. 256.—ACUTE OSTEOMYELITIS.

Fig. 257.—CHRONIC OSTEOMYELITIS.

Plate XXII.

parts, as around a joint unused for a long period, or in early stages of tuberculosis before any definite lesion can be made out. The "fluffy" appearance of the thinned cancellous tissue, and the finely pencilled outline of the compact tissue (giving it a so-called "sketchy" appearance), may be seen in the head of the left femur in Fig. 204, on page 283, as compared with the right side of the same radiogram.

A further stage of *necrosis*—actual destruction of bone tissue by disease process—is shewn in Fig. 256, where the contour of the bone is markedly disturbed and the structure absent over a large area.

The formation of *sequestra* may be detected by radiography in the midst of bony tissue, as in Fig. 256, or in process of separation, as in Fig. 252.

Fistulæ or **sinuses,** leading to abscess cavities, as in Fig. 253, may be traced to their source by injecting their track by an opaque medium. Bismuth vaseline 20 per cent. is commonly advised, but, as pointed out by Macleod of Shanghai, a non-greasy medium will penetrate more readily by mixing with the watery fluids, pus, etc., contained in the track and in the communicating abscess cavity. Macleod recommends a mixture of one part of bismuth oxychloride in three to six parts of mucilage of acacia, and suggests that the part should be kneaded to secure admixture of the emulsion and pus, and that if cloth be suspected to be present in a wound so investigated, the injection should be drained away by gentle hand pressure before the radiogram is made.

Periostitis of some duration may usually be readily diagnosed from a radiogram, although very recent injuries may shew no evidence of damage which may later become apparent. In acute disease, or following injury, the limiting membrane may be seen as a thin wavy line separated from the bone at the part affected. Later, between that and the bone, may be a less dense shadow, produced by pus collected there. From such appearance the focus of origin of the pus may be determined to the exclusion of deeper disease of the bone.

In more chronic affections the periosteum will be represented by a thickened and more dense linear shadow, separated more or less from the shadow of the bone.

Fig. 254 represents such an appearance.

The originating cause of the periostitis must be determined from other evidence; on that point X rays give little, if any, guidance.

Hæmorrhage under the periosteum (see Fig. 277, on page 335) may loosen it from the shaft of a bone, and, in young children, this may spread for some distance along the shaft, whilst in an adult it will more probably remain localised.

Osteoperiostitis will shew, in addition to the above, a thickening of the bone at the affected part. This condition may closely resemble clinically the early stage of a malignant disease, but the well defined and uniform shadow of the compact bone will differentiate. Later, necrosis of the underlying bone will produce the appearances noted as accompanying rarefaction, and bone abscesses may further be revealed. Fig. 255 represents an advanced case in which remains of the original shaft of the ulna may be seen inside a new shaft in process of formation.

Osteitis shews localised destruction of bone with, or without, periostitis or myelitis, and may be masked considerably by the appearances of those accompanying conditions.

Fig. 260 shews the change in a spongy bone due to tuberculous disease.

Osteomyelitis.—Appearances depend upon the *stage* and *virulence* of the disease, its progress being marked by signs of *bone destruction*, its arrest and repair by *new bone formation*, the new bone indicating the limit of the infection.

(*a*) **Acute** (Fig. 256) if progressive, signs appear roughly as follows:—

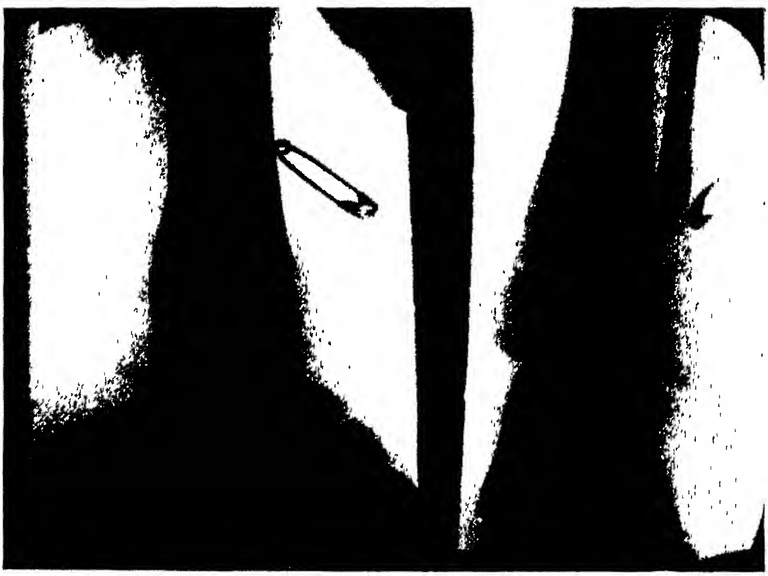
(i) For one or two weeks after infection there may be *no changes* evident in a radiogram.

(ii) *Outline* of bone becomes *less defined* than normal, and *areas of diminished density*, due to rarefaction of bone, appear, especially in the diaphysis near the epiphyseal line.

(iii) *Outline* may become *broken* and *irregular*, *periosteum* shews dense *thickening*, and *rarefaction* becomes *extensive* throughout the bone.

(iv) Irregular areas of *necrosis* appear scattered throughout cortex, separated by areas of normal bone.

(v) *Cavities* appear with irregular non-sclerosed outlines, and possibly enclosed *sequestra*.



Figs. 258 and 259.—NON-VIRULENT ABSCESS (BRODY'S)

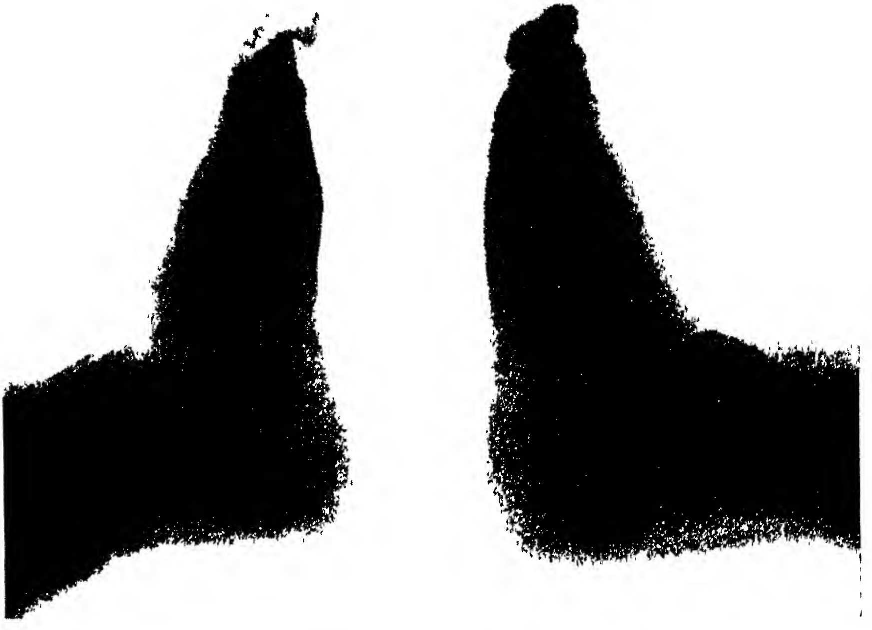


Fig. 260.—Tubercular Osteitis of Os Calcis.

Fig. 261.—Tubercular Disease (Advanced) of Radius.

(*b*) **Chronic** (Fig. 257) shews appearances similar in kind to the above signs of acute disease, but bone destruction is less marked and new bone formation correspondingly more evident.

(i) *Sub-periosteal bone* appears very *dense*, and may produce marked broadening of the bone shadow, which must not be mistaken for expansion of the bone from within (see differential diagnosis). *New bone* formation may encroach on the *medullary* cavity.

(ii) *Areas of necrosis* are small, and appear as areas of diminished density surrounded by more or less *clearly defined margins* of denser shadow, due to sclerosed bone.

(iii) *Abscess cavities* are also small with well defined regular margins; *sequestra*, if present, are small and may be obscured by dense shadow of surrounding sclerosed bone.

A so-called "*non-virulent bone abscess*" (*Brody's abscess*) may appear in the cancellous tissue at one end of a long bone (upper end of tibia and humerus being favourite sites) as a circumscribed area of rarefaction, with well defined margin of increased density and with little or no accompanying periostitis, as seen in Figs. 258 and 259.

Differential Diagnosis.—*Benign growths*, such as enchondromata and cysts, appear as if expanding the cortex from within, as contrasted with the deposition of sub-periosteal bone outside the cortex.

Malignant growths absorb all bone tissue as they advance radially as from a centre; their outline is less sharply defined and *no normal bone* appears between affected areas, nor are sequestra formed. Such growths are usually situated near an end of the diaphysis of a long bone.

Syphilis and *tuberculosis* produce changes resembling those due to pyogenic infection, and differentiation may be difficult or impossible otherwise than by consideration of clinical history. Tuberculosis may usually be distinguished by the appearance of atrophy of the neighbouring bones. Typical appearances are described on following pages.

Tuberculosis.—*Earliest bone changes* are those of *rarefaction*, described on page 318. Fig. 258 shews early *osteitic* changes in the right os calcis, as compared with the normal left. Changes in bone usually follow or accompany involvement of a neighbouring *joint*, of which the usual appearances are described on page 365. The increased transradiancy, coupled with the blurring effect of effused fluid in the joint, produces a *very indistinct outline*, with loss of detail, of the articular ends of the bones, and, if the other outlines and detail in the radiogram are clear, this lack of definition may be very suggestive of tubercular disease before any alterations in structure are apparent.

Later stages shew evidence of slowly progressive *destructive processes* without attempt at regeneration, the epiphyses of long bones and neighbouring diaphyses being usually first affected. The various changes described under osteomyelitis, on page 322, may appear, their nature depending upon the part of the bone affected, as determined by the locality of the initial focus of infection.

Periostitis may occasionally accompany bone changes, as in Fig. 254, in which cases syphilis may be closely simulated.

Erosion of surface and *necrosis* of bone substance appear as irregularities of outline (as in Fig. 261), or as areas of diminished density, the distinctness of outline of which depends upon whether the process of necrosis is still active or is arrested and new bone formation commenced (as in Fig. 262).

Fig. 262 shews a view of a case of primary bone origin Rarefaction is present, and the focus of disease, now an abscess cavity, involves both sides of the epiphyseal line. Sclerotic osteitis is evident around the cavity, and a small sequestrum is seen lying at its lower and posterior aspect, but the joint is not yet involved.

Sequestra appear, which are frequently round in shape, of indefinite eroded outline and of diminished density. Spicules or linear sequestra also may be seen. In rare cases, *confined to the shaft* of a bone, tuberculosis may produce localised but irregular destruction of the bone substance centrally, without affection of the surface or covering periosteum. Later involvement of the periosteum confuses the diagnosis with syphilis.

Fig. 262.—TUBERCULAR DISEASE OF LOWER END OF FEMUR.

Fig. 263.—DACTYLITIS-TUBERCULAR.

Fig. 264.—DACTYLITIS-TUBERCULAR OR SYPHILITIC.

Plate XXV.

Fig. 265.—TUBERCULAR SPINE WITH SINUS.

Fig. 266.—TUBERCULAR SPINE SHEWING ANGULATION AND WEDGE-SHAPE VERTEBRÆ.

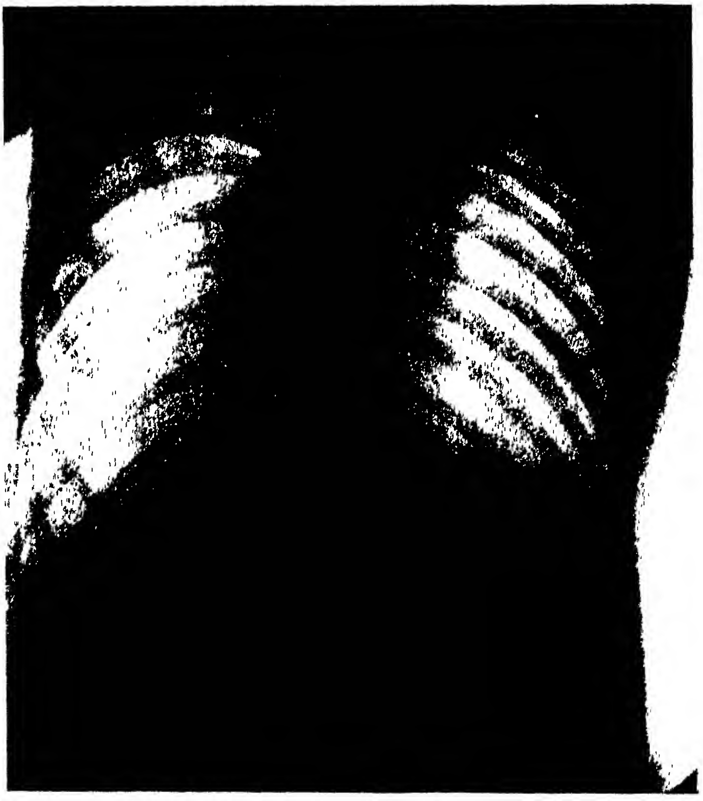


Plate XXVI.

Fig. 267.—TUBERCULAR SPINE WITH ABSCESS.

Tubercular Dactylitis shews increased diameter of the affected phalanx, destruction of bone substance centrally being accompanied by production of bone sub-periosteally.

Fig. 263 shews an early case, obviously tubercular, but Fig. 264 might be either tubercular or syphilitic.

In the spinal column tuberculous disease produces characteristic appearances dependent upon the special structure of that part. Commencing in the neighbourhood of the intervertebral discs the disease destroys the vertebral bodies, which gradually collapse, thereby producing sharp *angulations*. The anterior part of an affected body is almost invariably involved, and the body assumes the shape of a wedge with its thin end directed forwards, as shewn in Fig. 266. The resultant angulation is therefore posterior and not lateral, as in most non-tuberculous curvatures, and the angulation in its acuteness further contrasts with a curvature.

The intervertebral discs being destroyed, adjacent bodies appear fused, as in Fig. 265, where a sinus is seen leading to two partially destroyed vertebræ. This contrasts with the appearance produced by tumour, in which case the intervertebral discs are usually preserved.

Appearance of *abscess* may be the first radiographic evidence of disease, or the presence of that condition may mask the detail of bone structure, but frequently the approximation of bodies may be seen in a lateral view before abscess formation.

In tuberculous cases free from secondary infection, *new bone* production will be markedly *absent*, this serving to differentiate from other forms of arthritis, but secondary infection may result in new bone production and thereby confuse the diagnosis.

Arrest of tubercular disease process in any part is shewn by appearance of more distinct outlines, due to formation of new bone around areas of necrosis, accompanied by improved definition in detail of the bone structure.

Differential Diagnosis.—*Syphilis* is marked rather by sclerosis and new bone formation, whereas tuberculosis is characterised by atrophy alone. Periostitis is commonly more marked in syphilis, but in certain cases other clinical signs may be required for differentiation. In syphilitic dactylitis there is periosteal proliferation with little or no apparent involvement of the bone, but differentiation from a radiogram alone may be very difficult and should not be relied upon.

Pyogenic infection.—In certain cases radiographic appearances may be very similar. In acute cases rapidity of destructive processes, and in chronic cases the appearance of new bone formation may distinguish but clinical history and symptoms

Syphilis.—Appearances vary widely, according to the activity and duration of the process, ranging from a slight *periostitis* to an advanced *osteomyelitis*. *Periostitis*, as in Fig. 268 opposite, usually produces a *laminated* thickening of the bone subperiosteally, and also may cause *encroachment* on the medullary cavity. Early and active cases shew a fringed irregular outline which later becomes smooth with well defined margin. Periosteal thickening is usually greater on the *convex side* of a long bone, as in the "sabre tibia," which contrasts with rickets, where this change is more marked on the concave side.

There is usually *no atrophy* of affected bones, hence no fractures or deformities.

Congenital affection of the ends of long bones is seen from Fig. 269 to be a *diaphysitis* and not an epiphysitis, as frequently described.

Dactylitis shews marked periosteal changes with little, or no, apparent disturbance of the underlying bone; see Fig. 264.

A *gumma* affecting bone gives a somewhat characteristic appearance, casting a uniform shadow of density less than that cast by bone, but greater than that cast by tubercular areas, and having a more definite outline than the latter. In an early stage indefinite enlargement may be the main appearance, as in Fig. 270, but later a gumma causes rarefaction and erosion, with, or without, periosteal changes, producing a characteristic appearance, as in Fig. 271.

Syphilitic affections produce few characteristic appearances, but the condition may be suspected from :—

(1) Extensive changes seen in a radiogram with few clinical signs.
(2) Relatively great production of new bone.
(3) Osteitis without cavities.
(4) Multiple lesions.

Differential Diagnosis.—*Periosteal sarcoma* (1) is usually situated towards one end of a long bone; (2) shews spindle-shaped expansion of shaft and probably raised edge of periosteum at periphery of rarefied area; (3) strands of ossification radiate from centre of area.

Osteitis Deformans. See page 334.

(See also differential table on page 367.)

Actinomycosis produces a *chronic osteomyelitis* of slow progress and with very marked production of new bone, but with no distinctive X-ray appearances.

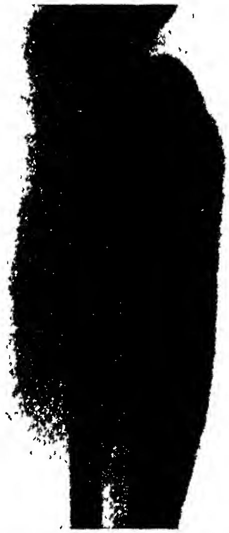


Fig. 268.—SYPHILITIC PERIOSTITIS.

Fig. 269.—CONGENITAL SYPHILIS.

Fig. 270.—GUMMA IN BONE.

Fig. 271.—GUMMA IN BONE.

Plate XXVII.

Fig. 272.—LEPROSY IN BONE.

Fig. 273.— RICKETS.

Fig. 274.—ACHONDROPLASIA. (ADULT.)

Fig. 275.—ACHONDROPLASIA.

Plate XXVIII

Leprosy produces *atrophy* of bone with *periostitis*, with a characteristic progressive absorption of the *terminal phalanges*, as seen in Fig. 272.

Rickets is made evident by altered form of the outline of the bony shadow, due to *irregular ossification*, both sub-periosteal and epiphyseal.

This is accompained by *general atrophy* of bone, leading to marked deformities and to fractures, greenstick and complete, and in repair of the latter excessive callus formation occurs.

At an earlier stage the borders of the *zone of proliferation* between shaft and epiphyses of long bones are seen to be irregular and ill defined, and the zone wider than normal. The end of the diaphysis is correspondingly irregular, and the part is very large compared with the epiphysis, giving a saucer shape to the end of the bone (Fig. 273). The *medullary cavity* of a long bone shews a widening and is correspondingly trans-radiant with possibly cystic areas.

Periostitis of slight degree may appear. When *recovery* from the condition takes place a white line appears (on a negative) at the end of the shaft adjoining the epiphyseal line, due to sclerosis at the epiphyseal line. Bones may become gradually dense and heavy, and if a shaft be bowed, thickening appears mainly on the concave side (contrasting with syphilis on the convex).

In *adults*, rickets produces an irregular rarefaction and enlargement of the long bones.

Differential Diagnosis.—*Osteogenesis imperfecta* does not show joint or epiphyseal changes.

Scurvy shews changes only on the shaft side of the epiphyseal line; that line is not affected and there is no saucer-shaped enlargement. Sub-periosteal hæmorrhage, if present, will denote scurvy.

Syphilis shews well defined areas of destruction near the epiphyseal line, but that line, if not destroyed, appears normal; periostitis is well marked, but atrophy is slight. (See also differential table on page 367).

Epiphysitis may sometimes be confused clinically with rickets. In epiphysitis the part will probably have its outline obscured by a foggy appearance, especially involving the epiphysis, of which the outline may be quite obliterated, and none of the typical appearances of rickets will be seen.

Achondroplasia (Fig 274), in contrast with rickets, shews shortened deformed bones of *very dense* substance, due to arrest of growth, with a reduced width of proliferating zone which is very definitely outlined. Periosteum is unaffected, and a long bone may appear as of normal width with broadened ends, as in Fig. 275.

Osteogenesis Imperfecta (fragilitas ossium), and **Osteomalacia** (mollities ossium) (Fig. 276).—Those two conditions shew somewhat similar X-ray appearances, although the former, met with in infancy, is classed clinically as congenital, and the latter, met with in advanced years, is classed as inflammatory.

The bones of the skeleton shew extreme and irregular *increase in transradiancy*, cortex reduced to a thin line and cancellous tissue of wide-meshed structure and "sketchy" in appearance.

Deformities and fractures are frequent and multiple, usually with little callus, but in infantile cases repair may occur with fair amount of callus.

There are no changes in the epiphyses, unlike rickets; thus, in infantile cases, no alteration in size will be noted, but in later years the shafts will appear narrowed and the epiphyseal ends expanded by contrast.

There is *no attempt at new bone formation*, this differentiating from Paget's osteitis deformans, in which dense bone formation occurs along with rarefaction.

Scurvy is marked by *periostitis*, and sub-periosteal *hæmorrhage* may later become evident as the blood clot organises or calcifies. Such hæmorrhages may be seen to the inner side of the lower end of each femur in Fig. 277.

The epiphyseal line is not affected, but adjoining it at an early stage a dense band appears in the end of the shaft (shewing as a white line in a negative.)

There are no changes in the epiphysis, but that may be dislocated by the sub-periosteal hæmorrhage. There is no destruction of the shaft and no cup-shaped enlargement of the ends. (See also differential table on page 367).

Osteitis Deformans (Paget's).—Affected bones shew *absence of normal bone structure*, their radiographic appearance being almost homogeneous, except for diminished density over the medullary space, and *longitudinal striae* produced by alternate transradiant and denser bone, as seen in Fig. 278.

So far as recognisable the cortex appears widened towards both aspects, and the medulla shews irregular cyst-like areas of rarefaction, which usually extend into the epiphyses; this extension serving to differentiate from *syphilis*.

Long bones become enlarged and deformed and fractures may appear. The *skull bones* shew expansion, produced by thickening of both tables, whilst round masses of bone appearing between the tables, and on the outside, produce a very characteristic *mottled* appearance, shewn in Fig. 279.

Fig. 276.—OSTEOMALACIA.

Fig. 277.—SCURVY, WITH SUB-PERIOST HÆMORRHAGE.

Fig. 278.—OSTEITIS DEFORMANS.

Fig. 279.—OSTEITIS DEFORMANS OF SKUI

Plate XXIX.

Fig. 280.—Osteitis Fibrosa-Cystica (with Hæmatoma).

Fig. 281.—Fracture through Bone Cyst.

Fig. 282.—Cyst of the Upper End of Humerus.

Plate XXX.

Osteitis Fibrosa Cystica (*fibro-cystic disease of bone*) shews replacement of bony structure by *longitudinal striae* of alternate density interspersed with *cyst-like areas* of varying size, as seen in Fig. 280.

The cortex shews considerable expansion and is extremely thin but intact. There is no sub-periosteal bone formation and no rarefaction of surrounding bone.

Deformity occurs with bowing of long bones and possibly fractures, as in Figs. 280 and 281.

Tuberculosis may resemble this condition, but areas of rarefaction are irregular in outline and encroach upon the cortex whilst decalcification and resultant transradiancy of surrounding bone will be marked.

The difficulties of classification are strikingly illustrated in this so-called "disease," which is described by many as of inflammatory origin (Baetjer & Waters).

Fig. 280 opposite is classed as "osteitis fibrosa," but if it be compared with Fig. 282, a striking similarity is apparent, whereas that latter figure is reproduced from the "Archives of Radiology and Electrotherapy" for January, 1923, from a paper in which Mr. Wakeley describes it as "*a cyst.*" In that paper is discussed the nature and classification of fibro-cystic changes in bone, and it is concluded that all should be meanwhile classed in one group without assumption of the nature of the process or processes producing them.

Acromegaly shews general *enlargement* of bones with cancellous texture appearing coarse and heavy, the enlargement of the terminal phalanges being particularly characteristic. The *skull* shews enlargement of the frontal bone and sinuses, and lengthening and protrusion of the lower jaw, whilst the sella turcica will probably appear enlarged and deepened.

Hypertrophic Pulmonary Osteoarthropathy.—Affected bones shew raised periosteum ; this being most common in metacarpals, metatarsals and phalanges, but occasionally extending to all long bones.

Partial calcification of the periosteum later produces a denser outline with a clear space between that and the cortex, whilst the underlying bone is unchanged. The distal ends of the fingers will probably shew typical clubbing of the soft tissues.

"**Koehler's Disease**" (Fig. 283) occurring in children of age from about three to eight years, may be described as a hyper-calcification or osteochondritis in the *scaphoid* of the foot, and appears as a *compression* of the ossification centre, the shadow of the affected part being reduced in size and increased in density as compared with the normal appearance. The opposite foot may serve for comparison, but at times, where symptoms have appeared only in one foot, the other scaphoid will be found to shew a similar abnormality. The dense shadow may shew lamination or may be divided into two parts, but development proceeds normally after a therapeutic period of rest to the foot, as shewn in opposite figure, 284, reproduced from a

Fig. 283.—Koehler's Disease of Scaphoid.

paper by Thurstan Holland. The other bones of the foot and neighbouring structures are unaffected.

Tuberculosis would, in addition to reduced size of ossification centre, shew rarefaction of neighbouring bones and a reduction of the cartilaginous interval between the scaphoid and adjacent bones. The possibility of simultaneous affection should, however, be borne in mind.

"**Schlatter's Disease**" (Fig. 285) shews a *separate* and *divided* epiphyseal nucleus of the *tibial tubercle*. This may be displaced upwards by the quadriceps muscle, and the margins of the epiphyseal line between tubercle and tibia will be thickened and ragged. The soft tissues may shew increased density, so as to mask the appearances slightly, but the knee joint is otherwise normal.

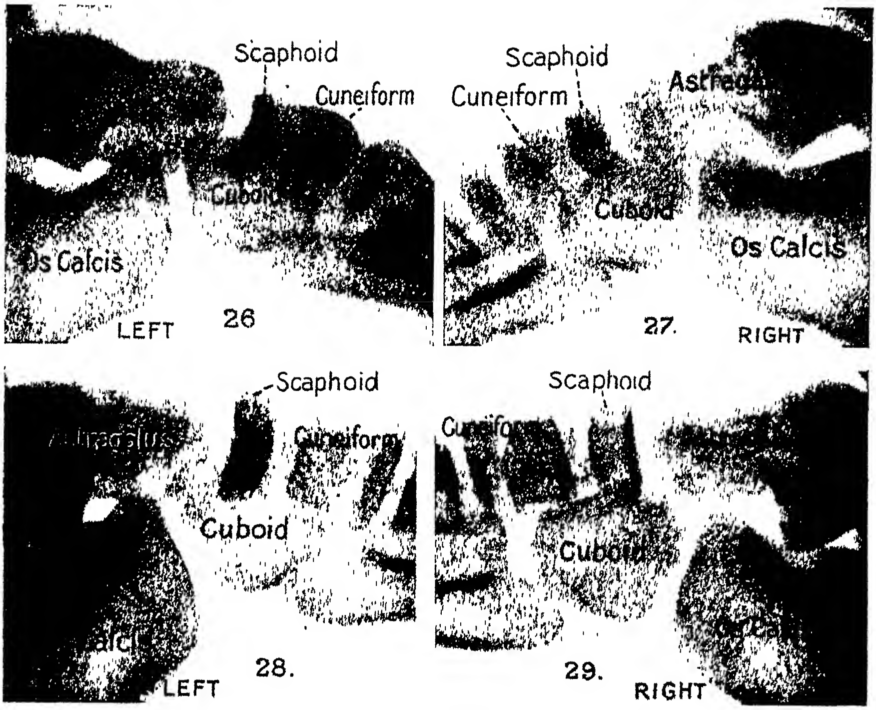


Fig. 284.—(26 and 27) KOEHLER'S DISEASE IN LEFT FOOT CONTRASTED WITH NORMAL RIGHT, AGE 9 YEARS. (28 and 29) LEFT AND RIGHT FEET TWENTY MONTHS LATER.

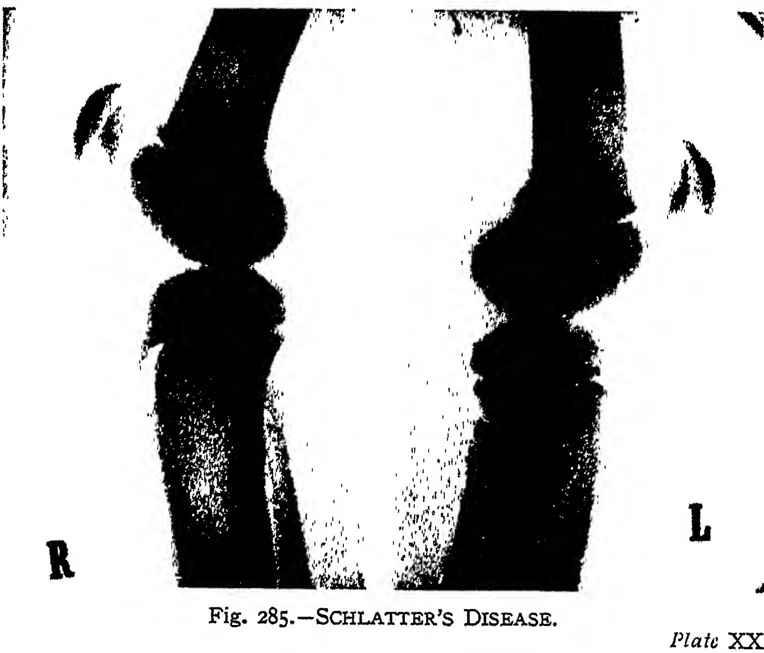


Fig. 285.—SCHLATTER'S DISEASE.

Plate XXXI.

Fig. 286.—PSEUDO-COXALGIA (PERTHE'S DISEASE) OF LEFT HIP.
Fig. 287.—SAME CASE TWELVE MONTHS LATER.

Plate XXXII.

Pseudo-Coxalgia: "**Perthe's Disease,**" *Legg's Disease* (*osteo-chondritis deformans*) occurring in children from about four to ten years of age, may, it its early stages, readily be confused with tuberculous disease.

It is primarily an affection of the epiphysis, whether its cause be traumatic or infective is still under discussion.

No definite appearance can be said to be typical of the condition, but one or more of the following radiographic signs are always evident:—

(i) *Flattening and increased density of the epiphysis* of the head of the femur—due to hypercalcification—usually with separation into fragments;

(ii) *Widening of the femoral neck*, particularly at the epiphyseal line;

(iii) *Irregularity of the acetabulum* at its upper lip;

(iv) *Rarefied areas* either in femoral neck or acetabulum;

(i) and (ii) being the chief diagnostic signs.

With a normal recovery the rarefied areas completely disappear, as also the irregularity of the acetabulum; but widening of the femoral neck remains, along with a deformed mushroom-shape of the head of the femur, to accommodate which there may be a slight alteration in the upper lip of the acetabulum. Fig. 286 is from a case before treatment, and Fig. 287, from the same case twelve months later, shews the absence of any destructive change. This prognosis is in striking contrast with *tuberculous disease* producing a similar degree of alteration in appearance.

Differential Diagnosis.—*Tuberculous arthritis* produces a general rarefaction in all bones forming the joint, and usually proceeds to destructive changes in epiphysis and acetabulum (see page 365).

Fig. 307, on page 352, reproduces a tubercular joint for comparison with Fig. 308, which is from a case of pseudo-coxalgia of about the same age. Symptoms in such a case of tubercular disease would of course be severe, whereas in pseudo-coxalgia the clinical symptoms experienced are slight compared with the changes revealed in a radiogram.

Infective arthritis produces general rarefaction and distinctive changes, as noted on page 357.

Tubercular or infective osteitis in the femoral neck may produce widening of the neck, but there are no epiphyseal changes.

(g) NEW GROWTHS IN BONE.

New growths in bone may be roughly classified as *benign* and *malignant*, but radiologically, as pathologically, border line cases will be met with.

Osteoma or Exostosis, congenital and benign, shews bone elements, possibly rarefied or abnormally dense, in abnormal situations blending into normal bone at their site of origin. Outline is clean cut, and there is no invasion or involvement of the normal bone.

(*a*) *Ivory* exostoses are *sessile*, smooth in outline and much denser than normal bone. They occur usually on the outer surface of a bone, occasionally on the medullary aspect. They may undergo malignant change, which should be looked for in invasion of normal tissue.

(*b*) *Cancellous* exostoses (Figs. 288, 289, 290) are *pedunculated*, commonly appearing as a spur of angular outline arising near one end of a long bone, and being directed away from the nearest joint. Shape may be lobulated, branching, tuberous, or conical. Cortex and medulla are continuous with those of the bone of origin, and their shadow is usually less dense than normal bone.

Those may produce pressure effects on adjoining bones, as in Fig. 291.

Differential Diagnosis.—(*a*) A slow-growing *central sarcoma* shews a *coarser* trabeculation in the expanded cortex as compared with the normal bone structure of a *sessile* exostosis and adjoining bone.

(*b*) An *ossifying periosteal sarcoma* may appear like a *pedunculated* exostosis with loosely arranged trabeculæ, but the normal branching nature of those trabeculæ contrasts with the periosteal spicules seen in the sarcoma (see page 350).

Chondromata or Cartilaginous Exostoses appear on the *outside* of bones, usually the bones of the hand or foot, as in Fig. 292. The bony outline shews a deficiency, and the surrounding bone appears uneven in density, whilst the tumour itself appears relatively *transradiant*. The cartilaginous matrix produces a *structureless* and homogeneous light shadow, whilst *islands* of bony material scattered in it produce small opacities of diagnostic significance. A chondroma may become surrounded by an opaque cortex and appear united to the bone by a pedicle.

Fig. 288.—EXOSTOSIS, EARLY STAGE.

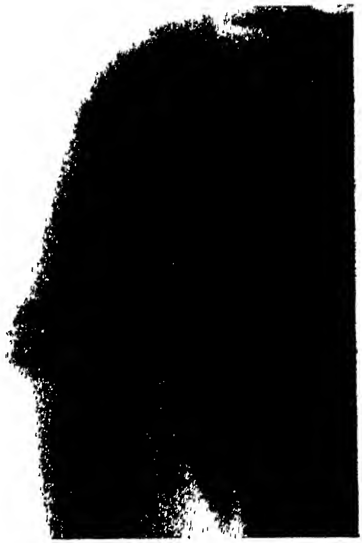


Fig. 289.—EXOSTOSIS OF HUMERUS.

Fig. 290.—EXOSTOSIS, CANCELLOUS OR PEDUNCULATED.

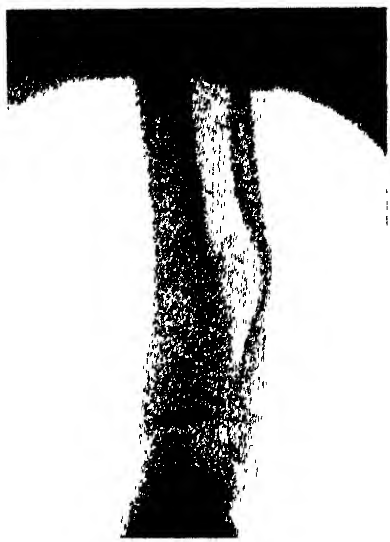


Fig. 291.—EXOSTOSIS PRODUCING PRESSURE EFFECTS.

Fig. 292.—Chondromata on Fingers of a Boy, Age 8 Years.

Fig. 293.—Enchondromata.

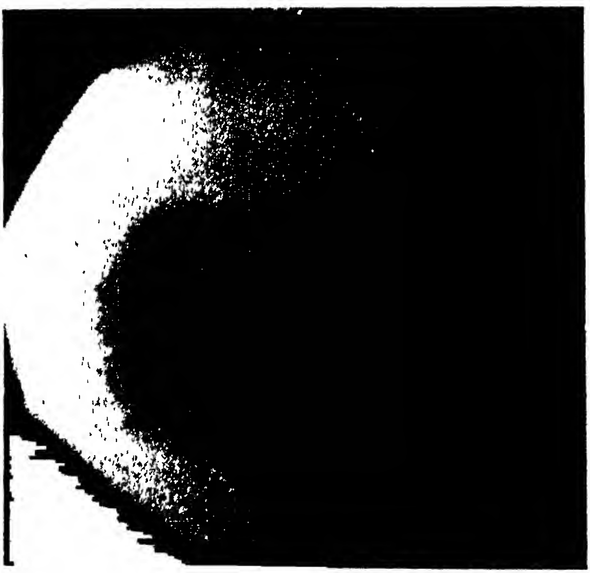


Fig. 294.—Osteochondroma.

Plate XXXIV.

Enchondromata (Fig. 293) arise in the *medullary cavities* of long bones, commonly in the hands and feet. An enchondroma produces a *transradiant cyst-like* appearance, possibly *loculated*, in the radiogram of the bone; the rarefied area of globular or spindle shape having sharply *defined limits* and bearing no suggestion of invasiveness. The cortex of the bone may be thinned by pressure, and coarser trabeculæ may appear at the site of pressure, but there will be *no* appearance of *bone destruction* nor of *new bone* formation, although the bone enlarged eccentrically may rupture, or a spontaneous fracture may occur, when resolution may take place and new bone follow. The radiographic appearance of the tumour itself will be like that described above for a chondroma, and the *small opacities* are equally valuable for differential diagnosis.

Osteochondromata (Fig. 294) shew signs of calcification or ossification imposed upon the appearances described above.

Cysts appear in the medulla of a long bone or of the jaw, usually near an epiphysis, and produce appearances *closely resembling those of enchondromata*. A cyst may be loculated, but is not usually so. Enchondromata are more likely to be multiple in occurrence, and appearance of the small opacities referred to may define the diagnosis, but otherwise the appearances described above for chondromata or enchondromata may equally well be applied to a cyst. Regarding the nature and classification of cysts, see note on "fibro-cystic disease," on page 337.

Differential Diagnosis.—*Myxoma* and *fibroma* are rare tumours, single in occurrence but *indistinguishable* radiographically from enchondroma or cyst.

Central (or endosteal) sarcoma occurs usually near one end of the shaft of a bone and shews *early expansion and rupture* of the bony limit, this destruction of the cortex being accompanied by production of more or less periosteal *new bone*. This new bone may differentiate from enchondroma, but occurrence of small opacities in the transradiant area of the latter will identify it.

Bone abscess shews predominating presence of *new bone*, producing a dense ring surrounding the rarefied area, whilst sub-periosteal new bone will produce more or less enlargement of the shaft.

Tuberculosis may produce a circumscribed area of rarefaction, but this will usually be *irregular* in outline and density, and there will be no enlargement or expansion of the shaft.

Surrounding bone will further shew appearances of *rarefaction and atrophy*, as described on page 318.

Sarcoma.—Malignant tumours are variously classified, according to their rate and manner of *growth*, their seat of *origin* or the nature of their *constituent cells*. The first factor is the only one that may be said to concern the radiologist directly, since it is the only one regarding which he can furnish definite information to the surgeon.

Attempts to classify radiographic appearances, according to pathological classification, into myeloma, myeloid, endosteal and periosteal sarcomata, or into giant-celled, round-celled or spindle-celled varieties is worse than futile; it may be very misleading.

If the radiologist can say from his records whether the observed tumour shews signs of *malignancy*, whether its rate of progress appears *slow* or *rapid*, and whether that progress seems to be *central* or *peripheral* in direction, he is supplying valuable information which the surgeon will correlate with his own observations of signs and symptoms, so as to define the class of tumour and decide upon its appropriate treatment. In this, as in all other X-ray diagnosis, the radiologist should confine himself to *observed facts*, and avoid hypotheses which he is not in a position to test, and regarding which his opinion may not be desired.

For purposes of description all sarcomata of bone may be divided into *central* and *peripheral*, according to whether their observed progress and spread is mainly in the medullary cavity of the bone or mainly into the soft tissues surrounding the bone. Appearances noted will then indicate whether the rate of growth is slow or rapid, and the degree of malignancy will be denoted accordingly, but repeated observations may be necessary to form and to check such opinion.

Central Sarcomata appear mainly in the medullary cavity near the ends of long bones, and tumours of very low malignancy may seem to be confined entirely to the medulla, but that does not exclude their possible origin from spongy bone of the diaphysis and early progress centrally. Rate of growth varies from a very low malignancy—practically *benign*, as in so-called *myelomata* or *giant-celled sarcomata*, Fig. 295, through *slow-growing*, so-called *myeloid* sarcomata, Figs. 296 to 299, to *rapid-growing*, so-called *endosteal* sarcomata (*round or spindle-celled*), Fig. 300.

Appearances noted in a radiogram will vary according to the rate of growth :—

Fig. 295.—Central Sarcoma of Slow Growth, showing Repaired Fracture.

Fig. 296.

Fig. 297.

Fig. 298.

Figs. 296, 297 and 298.—Central Sarcomata of Medium rate of Growth in Various Situations and Stages.

Plate XXXV.

Fig. 299.—Central Sarcoma, of Medium Rate of Growth, in Advanced Stage.

Fig. 300.—Central Sarcoma of Rapid Growth.

Fig. 301.—Peripheral Sarcoma—Periosteal.

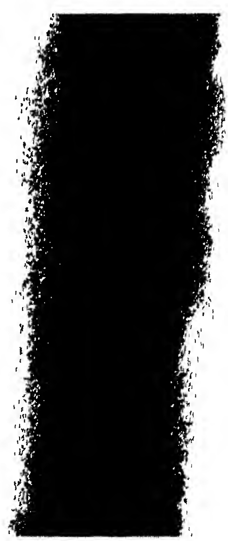


Fig. 302.—Peripheral Sarcoma involving Cortex.

Plate XXXVI

(i) A *slow-growing* tumour gives rise to (*a*) *expansion* of the bone shaft due to periosteal irritation and formation of new bone (striving, as it were, to limit and localise the disease process); (*b*) *coarse trabeculæ* due to absorption of normal bone and formation of ridges of surviving or new bony material over the area of pressure on the bony wall enclosing the tumour. Those produce a loculated appearance of the otherwise rarefied shadow of the tumour; (*c*) *well marked edge* of slow advance in the medulla and definite limits of the tumour within a bony shell, which may, however, become very thin. Figs. 296, 297, and 298 shew various stages of such tumours. If fracture should occur through the site of such a tumour repair may take place and union, as shewn in Fig. 295.

(ii) An *advancing* tumour further causes rupture of the enclosing wall of bone, the trabeculae and consequent appearance of loculation become less marked, the limits of the growth are less well defined and the soft tissues are invaded. If a joint be involved, the articular cartilage remains intact even in rapid growth. Those various points are well shewn in Fig. 299.

(iii) A *rapidly-growing* tumour is characterised by appearance of *extensive rarefaction* without any trace of bone structure within the rarefied area, which may extend *beyond the bone* into the adjacent soft tissues, as seen in Fig. 300. *Destruction of the cortex* will be complete, and expansion may not be very apparent since little time may be given for production of sub-periosteal new bone. There will be no definite outline to the tumour in the bone, but *normal bone structure* may be traced right up to the limit of the growth, both in the cortex and medulla. Secondary tumours often shew those characteristics more clearly, and such a growth in the ulna is shewn in Fig. 303, whilst Fig. 304 shews in the clavicle a typical "bone eater."

Differential Diagnosis.—*Enchondromata* are more definitely limited, shew no new periosteal bone, may occur at any part of a bone and will usually be multiple; appearance of small opacities in the transradiant area indicates chrondroma.

Cysts shew no trabeculæ like those appearing in slow-growing central sarcomata, nor any new bone formation, whilst well defined limits will differentiate from a rapid growth.

Osteomyelitis, if virulent, might suggest in appearance a rapid-growing sarcoma, but periostitis and osteitis will be marked, whilst areas of necrosis separated by normal bone will probably be found, and possibly sequestra. The history and clinical signs should obviate any confusion.

Peripheral (or Periosteal) Sarcomata are usually of *rapid growth*, as their early *invasion of the soft tissues* would indicate. The *cortex* of the bone may not show much appearance of invasion (true periosteal), and the tumour shadow will then be seen entirely amongst the soft tissues, with a faint but definite line of limitation. The *periosteum* in such cases, at an early stage, may only show slight thickening; or slight erosion of the cortex may appear with raising of the periosteum, well seen in Fig. 301. In other cases bone destruction may be evident along with the invasion of the soft tissues, as in Fig. 302, and the *medulla* may also be invaded. It is in such cases that attempts to define the seat of origin seem futile for the radiologist, and transitional stages and cases of all kinds commonly occur.

Except in cases of extremely rapid growth, a very characteristic appearance is produced in those tumours by the deposition in them of *radial striæ* of irregular ossification. Those appear as dense rays roughly perpendicular to the shaft of the bone and radiating into the indefinite shadow of the tumour as it invades the soft tissues.

Those "periosteal spicules" vary in number, and, as mentioned, if growth of the tumour be very rapid they may be very few, and bone destruction will then be the dominant appearance. A small group of such spicules appearing in a case diagnosed as periostitis, or in any chronic bone condition, should always be carefully noted as indicating a superimposed malignancy. Although the later stages are so characteristic and well marked, careful examination in the early stages of all such tumours is necessary.

Chondro sarcomata may show diagnostic small opacities (as in chondromata) in a faint shadow invading the soft tissues adjoining a bone before any bone destruction may be noted.

Osteosarcomata is a term applied in some classifications to slow-growing tumours with early and extensive deposition of lime salts, but in others it is applied to the type of central sarcomata described above as invading the bone cortex and medulla of the bone as well as the soft tissues.

Differential Diagnosis.—*Periostitis* shews new bone parallel to shaft.

Myositis ossificans shews well defined laminated or flaky masses in soft tissues parallel to shaft.

Exostosis shews a definite outline and no suggestion of bone destruction.

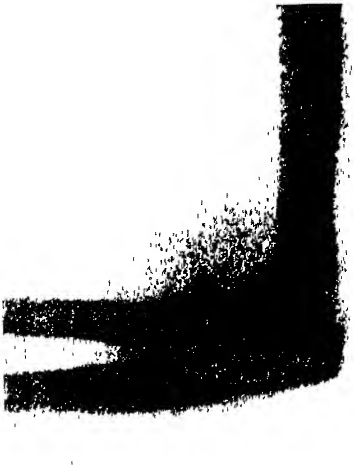


Fig. 303.—SECONDARY GROWTH IN ULNA.

Fig. 304.—SECONDARY GROWTH IN CLAVICLE (A "BONE-EATER").

Fig. 305.—SECONDARY GROWTH IN SCAPULA.

Fig. 306.—SECONDARY GROWTH WITH FRACTURE AND REPAIR.

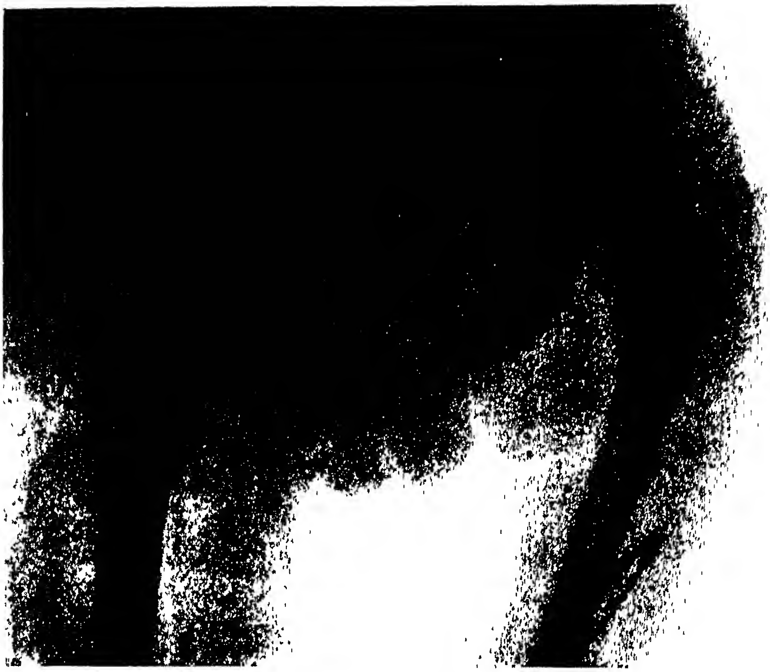


Fig. 307.—TUBERCULOUS DISEASE OF HIP-JOINT.
Note considerable destruction of head of femur and acetabulum, with rarefaction of adjoining bones.

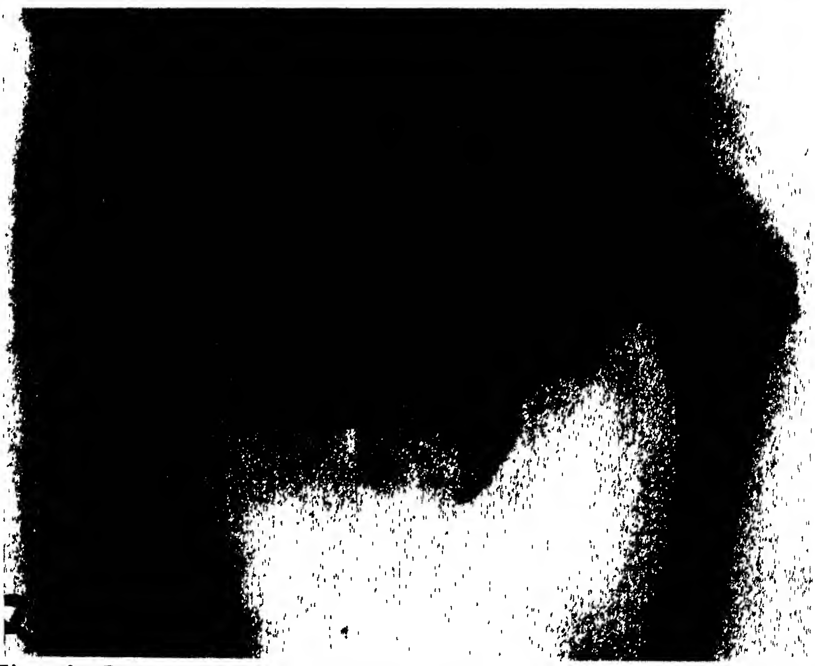


Fig. 308.—PSEUDO-COXALGIA (PERTHE'S DISEASE) OF HIP-JOINT IN CHILD OF SAME AGE AS Fig. 307.
Note flattening of head of femur and thickening of neck, with absence of rarefaction.

Plate XXXVIII.

Gummata will usually be multiple and confined to the bone, with a regular and distinct outline; if extending beyond the bone there will be no new bone apparent, either periosteal or within the tumour.

Secondary Tumours occurring by metastasis in bone cannot be classified directly by radiography, sarcoma and carcinoma producing similar appearances, those appearances being reproduced in Figs. 303, 304 and 305. Such a metastatic tumour appears as a *localised transradiant area* breaking the continuity of a bone and extending amongst adjoining soft tissues as a comparatively denser area shading off into the normal tissue. The bone surrounding the lighter area has an *eroded* appearance and may shew signs of *bone destruction.*

Compared with a primary malignant tumour, as described in preceding paragraphs, the *cortex* of the bone does not usually appear expanded but is *destroyed*; and there is *no new bone* production, except in a rare variety of very slow growth (mentioned later).

Spontaneous fracture may occur, as in Fig. 306, and, in exceptional cases, union may follow with callus formation, which may complicate the diagnosis.

Secondary tumours commonly occur near the middle of the shaft of a long bone, in the vicinity of the nutrient artery.

Carcinoma of the prostate, more rarely of the *breast*, if reproduced in a secondary tumour may show production of new bone, because of its very slow rate of growth, and for the same reason the secondary tumour may show a definite outline of dense shadow. Irregular dense areas may also appear in the transradiant area of the tumour, producing a coarse mottled appearance somewhat resembling osteitis deformans.

Differential Diagnosis.—The appearance of rarefaction produced by an early secondary tumour may resemble that of *tuberculosis*, but in the former there is no appearance of rarefaction or atrophy in the adjoining bones, and irregular dense areas appear between areas of destruction.

A bone infiltrated by a secondary tumour usually retains its normal volume and position, whereas in tuberculosis compression of the affected parts takes place early.

In the spine this absence of compression and collapse of the affected vertebræ is very striking as compared with a similar stage of tuberculosis or syphilis.

(*h*) DISEASE OF JOINTS

Diseases of joints are made evident by alterations in the transradiancy of their fluid contents, of their synovial membranes, or of the adjacent cartilage and bone; more advanced cases show further changes in contour of the latter structures.

Confusion in classification and nomenclature of joint affections renders discussion always difficult; but such classification must be based upon certain well recognised conditions which are here described, and detailed differentiation, in most cases, will further depend upon a full clinical history and examination of the cases concerned.

The appearances found will depend upon the stage of the condition under review, practically all joint conditions passing through the same stages, which may be classed roughly in succession as:—

(1) *Swelling* of the surrounding tissues including synovial membranes, producing a haziness of the joint outlines.

(2) *Increase of fluid* in the joint, producing a further haziness varying with the type of fluid and causing separation of the articular surfaces, evidenced by widening of the transradiant "joint space" between the bone shadows.

(3) *Destruction of cartilage* which, as fluid is absorbed, is evidenced by a narrowing of the joint space between the underlying bones.

(4) *Destruction of bone* evidenced by appearances described in preceding sections.

(5) *Production of fibrous tissue or new bone* accompanying (3) and (4) in chronic cases, or following the destructive stages after subsidence of that phase in acute cases.

Where the disease process does not pass beyond stages (1) and (2), that is, without evidence of any destructive changes, as in (3) and (4), stage (5) should not be anticipated, and recovery may be predicted without any permanent impairment of the joint.

Fig. 309.—Synovitis from Tubercular Disease of Ankle.

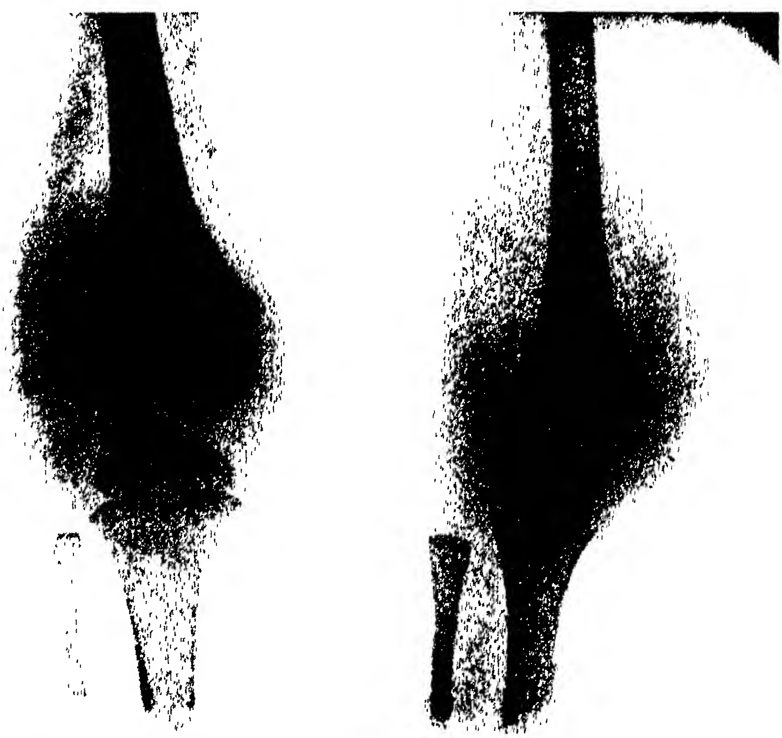


Fig. 310.—Synovitis from Tubercular Disease of Knee.

Plate XXXIX.

L,  R

Fig. 311.—Infective Arthritis (Active) in Right Hip.

L.  R

Fig. 312.—Infective Arthritis (Chronic) in Left Hip.

Plate XL.

Synovitis, as commonly understood, is evidenced by a general *lack of definition* of the outline of the structures constituting the affected joint, along with which there may be a darkening of the usual clear space between articulating surfaces.

Unless an appropriately soft tube be used this may appear only as a general "fuzziness," hard to differentiate from an extra synovial cellulitis. This is shewn in Fig. 309 accompanying tubercular disease of the ankle. Where fluid is present, the boundaries of that should be discernible in a good radiogram, and the separation of the articular surfaces will also be notable, as in Fig. 310. In more chronic cases the hypertrophied synovial fringes may be evident.

Arthritis shews the same changes in a further degree, along with some distortion and possibly loss of the articular cartilages. Those latter may shew increased density approaching that of the underlying bone, or, in a progressive acute case, appearances indicative of erosion and disintegration of the joint structures.

Ankylosis of a joint will be evidenced by the obliteration of the normally clear inter-articular space, so that the adjacent surfaces of the articulating bones are not separately recognisable.

For purposes of description the various types of arthritis may conveniently be classed as follows:—

1. Acute or infective polyarticular.
2. Chronic: (i) infective; (ii) atrophic—rheumatoid (atrophic)—deformans; (iii) hypertrophic—rheumatoid (hypertrophic)—osteo-arthritis.
3. General conditions affecting joints.

1. **Acute Polyarticular Arthritis** shews *no definite X-ray appearances*, those being confined usually to the swelling and fluid detailed as (1) and (2) of appearances noted on page 354. There may be a slight increase of transradiancy of adjoining bones due to disuse, but before that appears the condition has probably passed into a chronic stage.

2 (i) **Chronic Infective Arthritis** in addition to, or following, the above appearances shews *progressive atrophy of bone* and surrounding parts, due to disuse (see left side of Fig. 204, on page 283), and more or less *destruction of cartilage* and *bone*, followed by *production* of fibrous tissue or new bone.

In Fig. 311, opposite, the process is probably active, and destructive appearances are more evident; in Fig. 312 the process is more chronic, and new bone production is more definite.

The new bone will be apparent in the X-ray picture, and will be detected first at the points of attachments of the joint ligaments; fibrous tissue will show no evidence beyond a clouding of the joint space, and possibly bands of indefinite outline.

The various infections produce similar conditions and appearances, which give no clue to the specific causative agency, with the possible exception of *tuberculosis*; but in the early stages of that disease, as in other general diseases affecting the joints, the adjoining bones must be referred to for differential appearances. Those are noted later.

(ii) **Atrophic Arthritis,** *rheumatoid arthritis* (*atrophic*), or arthritis deformans, is marked by progressive *atrophy of the articular cartilages* and later *erosion.*

Those changes in the articular cartilages may be evident directly from their outline, or indirectly by the closer approximation of the surfaces of the underlying bones. The outline of those surfaces is distinctly marked in correspondence with their *sclerosis or eburnation*, and in contrast to the adjoining *cancellous bone*, which undergoes rapid and extreme decalcification, with consequent *increase in transradiancy.*

In its earlier stages this may readily be confused clinically with gout, but in a radiographic examination the absence of deposit, as described later in "gout," serves to eliminate the latter from the diagnosis.

As seen in Figs. 313 and 314, the appearance of joints affected by rheumatoid arthritis of atrophic type is very characteristic. There is a general, though somewhat indefinite, change in the whole appearance of the bones and joints. Whilst the outlines are distinct the bone tissue is on the whole more transradiant than normal, and in parts this amounts to an appearance indicating actual necrosis. Atrophy of the bones later becomes apparent. Most characteristic is the punched-out appearance of the erosions in the heads of the metacarpal and phalangeal bones, while in other joints erosion and disintegration may have proceeded to the extent of practically obliterating the joint.

(iii) **Hypertrophic Arthritis,** *rheumatoid arthritis* (*hypertrophic*) or *osteo-arthritis*, as represented in Fig. 315, is characterised by more or less distortion of the joint, along with

ATROPHIC ARTHRITIS (RHEUMATOID).

Fig. 313.—EARLY. Fig. 314.—ADVANCED.

Fig. 315.—OSTEO-ARTHRITIS (HYPERTROPHIC).

Fig. 316.—OLD OSTEO-ARTHRITIS SHEWING CALCIFIED ARTERIES.

Fig. 317.—LATERAL VIEW OF SPINE WITH ARTHRITIS.

Fig. 318.—GOUT IN FINGERS.

Plate XLII.

outgrowths of ossified cartilage—so-called "osteophytes." The fringe of osteophytes and accompanying irregular lipping of the margins of the cartilages are very characteristic.

Outlines are *clear and sharp-cut*, since there is no swelling or fluid to obscure them, nor is there any decalcification or atrophy of adjoining bones—those are, indeed, probably denser than normal, as seen in figures 315, 316 and 317.

There is no general atrophy nor destruction of the articular cartilages, but there are small areas of destruction from which exostoses arise, as well as from the points of attachments of the joint ligaments. Occasional irregular pieces of calcified cartilage also appear lying free in the joint space, so-called "joint mice."

3. **General Conditions and Systemic Diseases** in many cases produce local manifestations in and about joints which render the examination of those localities serviceable, even in the diagnosis of the general condition.

(i) **Gout.**—Particularly in the differentiation of joint affection due to gout from the closely simulating condition due to rheumatoid arthritis is an X-ray examination useful.

Whatever be the correct ætiology or theory of causation of gout, general or local, the characteristic process in the joint regions is a *deposition of salts of uric acid.*

Those salts collectively offer to the passage of X rays a resistance varying between that offered by bone and that offered by the less dense tissues of the joint. The different salts vary in density according to the base with which the uric acid is combined. The salts of calcium and magnesium are more dense than the others; and since those salts are usually present in all gouty deposits in greater or less proportion, a distinct evidence of the abnormality is obtained on radiographic examination.

The finger joints are, for several reasons of convenience, the most desirable parts to inspect. There the earliest evidence of uratic deposit will be found on the sides of the phalanges viewed dorso-ventrally.

As shewn in Fig. 318, shadows of somewhat indefinite outline will be seen *where the lateral ligaments of the joints are inserted into the bone.* The normal outline of the bone

may be seen through those shadows, or, in further advanced cases, the abnormal shadow may encroach, as by erosion, on the bone. Those small areas show sharply cut margins giving a "*punched out*" appearance.

Later changes are seen in the articular cartilages, those becoming more opaque to the rays, while their outlines are *distorted* and more or less *eroded*.

Some parts of the bone appear more transradiant in cases of gout, apparently by change in their mineral composition; but this is a somewhat indefinite appearance, and the evidence of uratic deposit is sufficiently characteristic and distinct to rely upon in most cases.

Early cases may show small *spurs of new growth*, resembling hypertrophic arthritis, whilst late severe cases in a large joint may show appearances of destruction resembling an early "Charcot joint." Accompanying appearances considered in association with clinical evidence will serve, however, to differentiate.

(ii) **Charcot's Disease** (Figs. 319 and 320) occurring in cases of tabes or syringomelia, shews *extensive swelling* of all parts with *copious fluid* effusion, and *widespread destruction* of articular cartilages proceeding to complete disorganisation of the joint. There is *no decalcification* nor atrophy of adjoining bone, and the remaining cartilage is denser than normal, so that the picture may have very clear cut outlines. Scattered throughout the joint in advanced cases may be seen large irregular pieces of calcified material.

Some Charcot joints may closely resemble hypertrophic arthritis. In acute cases the greater amount of effusion, the more advanced absorption of bone, and the absence of osteophytic outgrowths, may distinguish Charcot's disease. In more chronic cases, however, those distinguishing features may not be evident, and differentiation must depend upon history of onset and other clinical points.

Fig. 319.—CHARCOT JOINT.

Fig. 320.—JOINTS IN SYRINGOMYELIA.

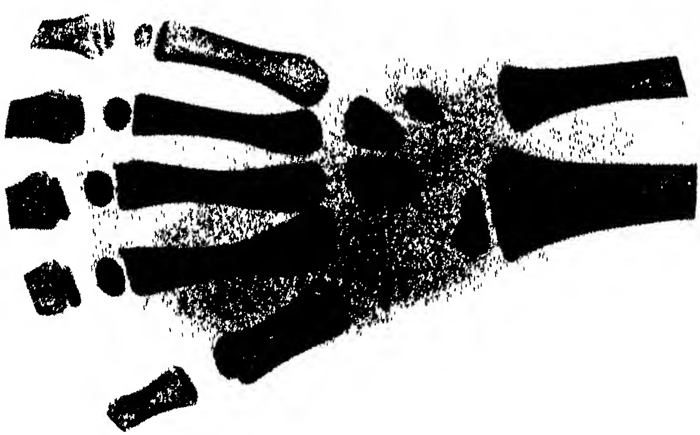


Fig. 321.—TUBERCULAR SYNOVITIS OF WRIST.

Plate XLIII.

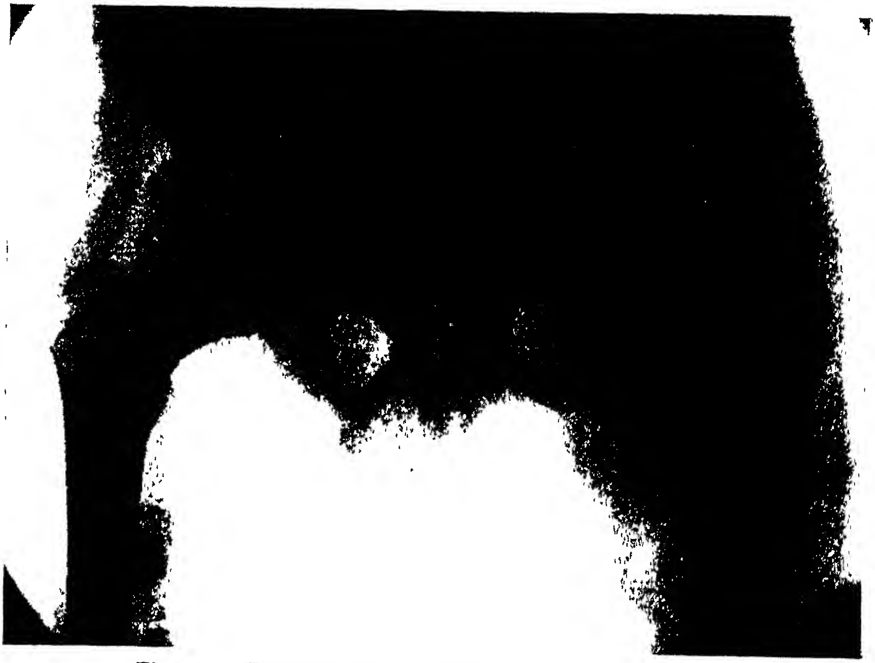


Fig. 322.—Tubercular Arthritis of Left Hip-Joint.

Fig. 323.—Advanced Tuberculous Disease of Elbow.

Plate XLIV

(iii) **Tubercular Joint.**—All cases of chronic arthritis are marked by the clearness of outline and structure of the adjoining bones (see Figs. 311 to 315).

This is in distinct contrast to tubercular joints, in which *blurring of outline* and detail is a typical feature. The appearance of this, as in the same disease affecting bone, will vary according to the stage or extent of the disease process.

In early cases may be discerned only a condition of *synovitis* or *arthritis* in the joint, as in Figs. 309 and 310, but by paying attention to the neighbouring bone or periosteum, the evidence there of contiguous disease may decide the nature of the joint affection. Fig. 321 is from a case of disease starting in the synovial membrane.

If the origin be in the *adjacent bone*, the appearances described as indicative of that condition will be evident, with possibly a sequestrum underlying the articular cartilage, as in Fig. 262, or the origin of the joint affection from an adjacent periostitis may be evident. If the disease originate in the *synovial membrane*, alterations in the adjacent bones will indicate a further stage of the disease process.

In either case later stages of the disease will be evidenced in a radiogram by a *reduction in density* of the surrounding bone and by an *indefinite mottled shadow* replacing the inter-articular clear space of the normal joint, as in the left hip-joint shewn in Fig. 322 opposite, and finally, by a general disappearance of outline of structures, as in Fig. 309 on page 355.

In the absence of positive signs of disease in the adjoining bones, the nature of the joint affection may be deduced from their *increased transradiancy*, and the clear "sketchy" outlines of the atrophied and decalcified bone contrasting with the hazy and indistinct appearance of the joint itself.

Later destruction of the articular cartilages will produce *narrowing of the joint space*, and the underlying bone affected by direct extension will appear *eroded* and irregular, until all appearance of structure may be obscured in advanced cases by an indefinite *mass shadow* of caseous material, as in Fig. 323, and, to a less extent, in Fig. 324.

There is *seldom new bone* formation in a tubercular joint except when secondary infection may have occurred.

Caries Sicca (commonly found affecting adult shoulder joints) shews irregular erosion of articular cartilage and underlying bone, appearing as a rarefied area with patches of increased density, accompanied by atrophy extending along the shafts of

the constituent bones. There is no swelling of surrounding tissues nor effusion in the joint cavity, so that the picture is clear and outlines sharply cut.

Differential Diagnosis.—*Acute epiphysitis* may resemble tubercular epiphysitis, but the picture is *not clouded and hazy*, as in a typical tubercular joint. The extension of the process is also less regular, and *isolated foci* appear as areas of rarefaction in the epiphysis without direct connection with the joint.

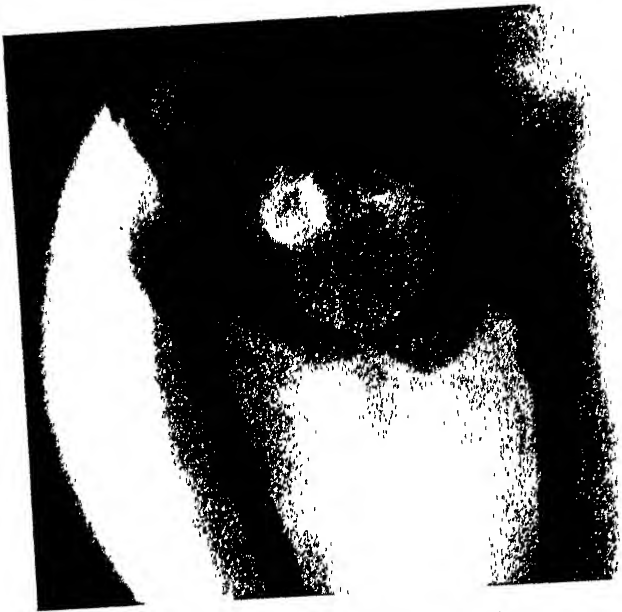


Fig. 324.—Tubercular Hip-Joint.

New bone formation in the later stages further distinguishes epiphysitis.

Perthe's Disease, described on page 341, might clinically be confused with a tubercular joint, but X-ray examination clearly distinguishes it by the *absence of haziness* or *erosion* of cartilage, whilst the *epiphysis* is not eroded but rather *increased in density*. See Figs. 307 and 308, on page 352.

(iv) **Syphilis**: (v) **Rickets**: (vi) **Scurvy**: all produce *multiple* joint conditions, resembling acute arthritis with *swelling* of peri-articular tissues and *fluid* effusion, but *without destruction* of articular cartilage. The conditions may, however, be differentiated by the adjacent bone changes, particularly in the region

of the epiphyseal line. Those changes have already been noted in detail on the pages indicated for each condition, and X-ray appearances are reproduced in Figs. 269, 273 and 277. The differential points are here summarised for reference :—

Rickets (page 333).	**Syphilis** (page 330)	**Scurvy** (page 334.)
Saucer-shaped *enlargement* of end of diaphysis, with irregular bone formation at epiphyseal line.	No general encroachment on epiphyseal line, but areas of osteitis in end of diaphysis, sometimes encroaching on epiphyseal line	Sclerosed area at epiphyseal line, with adjacent rarefied area.
Raised periosteum without increase in density of underlying bone: later deposit of periosteal bone on concave surfaces where bowed.	*Marked* periostitis, especially at chrondro-periosteal junction, with increase in density of adjacent cortex.	Periostitis with *hæmorrhage*, which may extend along shaft, or may dislocate epiphysis: later deposit of calcium salts.
Atrophy, *fracture* and *deformity*.	Slight atrophy, but *no* fracture or deformity.	

In the **Spinal Column**, from the nature of its construction, the appearances of arthritis are somewhat special to that region. The earliest stages are hard to detect, and bone production is usually the first sign to be detected. The edges of the vertebræ take on an appearance of *increased sharpness of outline*, especially at the sites of insertion of ligaments on either side of the intervertebral spaces, and a little later definite signs of bone formation (like exostoses) appear in those regions. This appearance is well seen in Fig. 317. The production of bone, the absence of any destruction or narrowing of the intervertebral discs, and the non-involvement of the vertebral bodies, serve to differentiate such arthritic conditions from tuberculosis.

A *spondylitis deformans* with calcification of ligaments may produce anterior bowing of the spine to such an extent that no intervertebral spaces are evident in an antero-posterior view, but a lateral view will reveal the true state of affairs.

The **Sacro-iliac Synchondroses** may show evidence, in blurring or disappearance of the cartilage line, of *arthritis obliterans*. This is said to be most commonly bilateral, in which case

several radiograms may be required to convince the observer that movement may not have blurred the outline; but in a unilateral case the contrast of the two sides shews up the condition beyond doubt.

Loose Bodies may, or may not, be discernible by X rays, their detection depending upon their calcification. Thus, as with calculi, a negative indication cannot be relied upon in opposition to other clinical evidence. Many loose bodies are, however, sufficiently opaque to give evidence of their presence by production of shadows, more or less dense, in abnormal

Fig. 325.—Loose Body in Knee Joint.

situations in or about a joint, as in Fig. 325. In certain situations care must be taken not to mistake for a loose body a sesamoid bone or an extra or abnormal centre of ossification. The latter are dealt with in discussing the various parts of the skeleton in the earlier pages of this chapter; a sesamoid commonly present in the outer head of the gastrocnemius muscle is discussed on page 286, where illustrations are shewn of a case which narrowly escaped operation by mistake. This is a familiar pitfall, but the oval shape with long axis vertical, having the density and structure of normal bone, should suggest a normal explanation. The posterior situation in a lateral view should further differentiate from a loose body in the joint, and final proof may be obtained by moving the joint whilst under screen observation.

(*i*) MUSCLE—SOFT TISSUES—SPINAL CANAL.

The soft tissues may produce shadows of slight density, but differentiation is only possible in a radiogram specially produced.

Abscess or exudation about a part will obscure the outline and produce a more or less dark shadow. Differentiation between various exudates is, however, not possible with any degree of certainty by X rays alone, and the nature of the exudate must usually be defined by other means.

Pus will usually be more circumscribed than blood or serofibrinous effusion.

Blood when organised casts a dense shadow, with irregular and shaded margin, while *serous* effusion may only be evident by the distortion of parts produced by its presence.

Fibrous adhesions are difficult to distinguish from normal connective tissue, but the presence of shadows in abnormal situations may indicate their occurrence.

Myositis Ossificans (Fig. 326) produces a characteristic shadow of flaky irregular masses of varying intensity without definite border amongst the substance of the muscle involved. A similar appearance is seen in calcification or ossification following *trauma of periosteum*, but the situation of the latter will usually differentiate, and in *calcified hæmatoma* (Fig. 329).

The shadow of *periosteal sarcoma* (see page 350), somewhat resembles the above, but is less definite in outline and shows encroachment on the normal bone structure, whilst the dense striæ radiate in the tumour in directions more or less nearly perpendicular to the surface of the adjoining bone, those of myositis ossificans being parallel.

Hæmangiomata may become plainly evident when calcification occurs, following thrombosis and fibrosis. In the soft tissues the angioma may appear as an ill defined *cystic* mass, and enclosed in this appear well marked *round* bodies of varying size, each with *concentric rings* of varying density. This is probably a rare condition, but two cases are reported in the "Archives of Radiology and Electrotherapy" for May, 1921, by Mr. Wakeley, as having been treated in King's College Hospital, London, in the preceding year.

Calcified Glands may cast a definite shadow, as in Fig. 327. Such glands are often seen in examining chests, and must also be remembered when inspecting radiograms for evidence of calculi in the urinary tract.

Trichina *encysted* in muscle and becoming *calcified* may produce a somewhat similar effect, as shewn in Fig. 328.

Hæmatomata produced by trauma under the periosteum of a long bone may undergo *calcification* after organisation of the blood clot, and may lead, without care, to a mistaken diganosis of *periosteal sarcoma.* The tumour from hæmorrhage, however, will be seen, as in Fig. 329, to be roughly *oblong* in shape, to have a *well defined* outline, and to follow the shaft of the bone *without encroachment* upon it, whilst the calcification will be in striæ more or less *parallel* to the shaft. In a malignant bone tumour there will be no sharply defined limits, the striæ of calcification will be roughly perpendicular to the shaft, and the shaft will be more or less encroached upon by the tumour.

Calcified Cysts may give rise to confusion if the possibility of their presence be overlooked; such cysts are shewn in Fig. 331, and in Fig. 382, on page 442.

Emphysema of the soft tissues produces a striking appearance in a radiogram, rendering the tissues infiltrated extremely transradiant and shewing up denser parts very clearly by contrast.

Gas Gangrene in the muscles surrounding an infected deep wound produces similar characteristic appearances. During the late war many interesting observations were made on the occurrence of this and on its X-ray appearances, but apart from war wounds it is happily a very rare occurrence.

Tumour in the Spinal Canal may be located by a method recently adopted, whereby an opaque fluid is introduced into the spinal theca and is allowed to gravitate towards the site of the suspected tumour.

Its arrest at the site of the tumour is later demonstrated on a radiogram, and precise localisation thus ensured before operation. *Lipiodol,* a heavy oily fluid containing 40 per cent. of iodine, and remarkably opaque to X rays, has been so employed, and its use, illustrated by radiograms from cases, is described by Mr. Percy Sargent in the *British Medical Journal* for 4th August, 1923.

Fig. 326.—Myositis Ossificans.

Fig. 327.—Calcified Glands.

Fig. 328.—Trichina in Muscle.

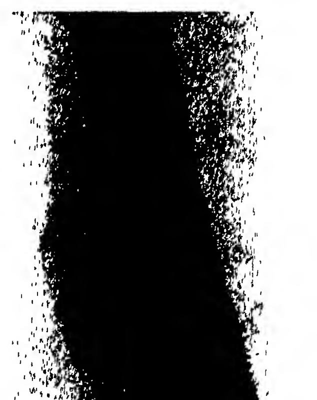


Fig. 329.—Ossifying Hæmatoma.

Plate XLV.

Fig. 330.—Carcinoma of Larynx.

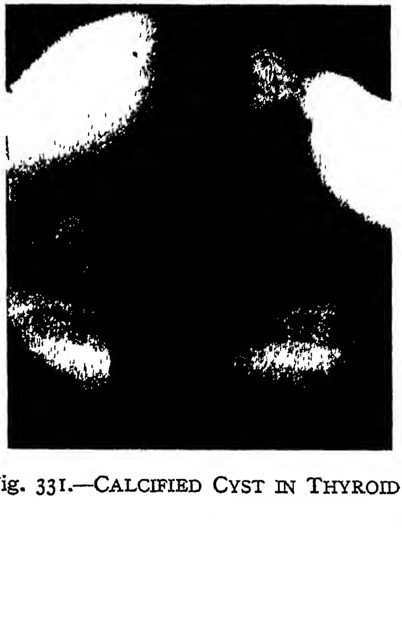


Fig. 331.—Calcified Cyst in Thyroid.

Plate XLVI.

CHAPTER X

DIAGNOSIS—RESPIRATORY AND CIRCULATORY SYSTEMS

Lungs, Heart, Aorta, Mediastinal Glands and Tumours

On examination of the thoracic organs much attention has been focussed by radiologists, but the limits of variation in the normal are hard to define. Indications of abnormality being entirely relative, considerable experience is required to form a definite opinion on views of this region, and wide experience enjoins caution in expression of such opinion.

The value to the clinical physician of X-ray examination of the chest has been much discussed, but, as a balanced opinion, the following sentences are quoted from the recent work on "Physical Examination of the Chest," by Dr. J. Crocket, Lecturer on Tuberculosis at Glasgow University (Lewis and Co., London).

He concludes that " as an aid to the diagnosis of tuberculous lesions the X rays are undoubtedly of great service. They remove all dubiety ; they give clear evidence of the extent of the lesion ; they demonstrate the area first affected, shewing that in almost 50 per cent. of the cases the hila are first involved, in 20 per cent. the upper apices, and in 30 per cent. the origin appears to be mixed."

In another chapter he says : " An X-ray examination of the chest should never take the place of a careful clinical examination. On the other hand, no chest should be reckoned to be completely examined unless it has been X-rayed. Such an examination may be regarded as having a four-fold purpose :—

" (i) Verifying the findings of other lines of examination ; confirming the form and the movements of the thoracic wall, the size, shape and site of the heart, the condition of the hilum structures and of the lungs, and the level, the contour and the amplitude of the movements of the diaphragm.

"(ii) Supplementing other methods of examination, enabling us to investigate more fully and more directly the various structures of the thorax. It is particularly useful in supplementing our methods of examining the condition of the para-tracheal structures and of the hila and other deep-seated tissues.

"(iii) Differentiating certain conditions. Paracentesis thoracis, for example, never needs to be resorted to in order to determine the presence or absence of fluid. The X rays unequivocally demonstrate its presence if it be there. The causes of median dulness, whether that be mediastinitis, aneurysm or neoplasm, may also thus be determined definitely in many cases.

"(iv) Recording permanently the progress of individual cases. As the cardiograph or the sphymograph gives records of the heart or of the pulse which can be compared or contrasted, so by the X rays we may have records of a patient from time to time showing the physical condition of heart and lungs."

Valuable assistance may, undoubtedly, be derived from X-ray examination in various conditions, but appearances noted should always be correlated with clinical history and with other physical signs before a definite diagnosis is expressed. Certain of those conditions are illustrated later, and to those illustrations are appended notes descriptive of them, but attention must first be directed to normal appearances and to general methods of examination.

Only as many illustrations are included as seem necessary to illustrate the text explanatory of the principles of thoracic diagnosis. For a comprehensive set of diagrams illustrating various thoracic conditions the reader should consult a work specially dealing with this region.

Larynx.—Of the larynx probably not much is to be learned from radiography.

Tuberculosis may be indicated by general haziness and indistinctness of outline, but such a diagnosis would be inconclusive. Carcinoma may produce irregularity of outline and distortion of form of the shadow, as shewn in Fig. 330, but the appearance there seen is probably due to coincident or

subsequent calcification, and such a case would probably be easily diagnosed otherwise.

A **thymus** or **thyroid** gland may, when enlarged, extend below the level of the clavicles and behind the sternum, and will appear as a widening of the upper end of the median shadow described in the following section.

Neither shadow will be dense and may easily be missed, except with a very soft tube, but the shadow when recorded will be sharply outlined and will be seen to extend upwards from the thorax proper beyond the clavicles. A *thyroid* may be distinguished by its movement with movements of swallowing.

Diversion of the Trachea by unilateral enlargement may also be noted in a radiogram.

A **Calcified Cyst** in the thyroid produces a striking appearance, as reproduced in Fig. 331, and might lead to confusion in diagnosis if unrecognised.

Radioscopy.—It is important to observe the extent and nature of the *movements* of the heart and diaphragm, as well as to note the outline and nature of the shadows cast by the thoracic contents. Hence the fluorescent screen is much employed in examining the thorax, and to a practised observer may give much information concerning the functional condition of the organs.

The screen should be placed in succession in front, behind, to the left side, and in what is known as the "right anterior oblique" position, the patient being rotated into the required position, or the tube set in each axis successively. Of the last position a special description is given later (see Fig. 370, on page 423).

In radioscopy or radiography of the thorax, especially for examination of pulmonary conditions, too hard a tube must not be used, nor should more current be employed than suffices to illuminate the healthy portions of lung tissue, otherwise many of the finer details of structure, upon which diagnosis largely depends, may be lost. Some of these finer details can be more efficiently observed on a radiogram, since the cumulative effect produced there enables the eye to detect appearances which it may fail to discern on the screen, but a preliminary screening is invaluable for certain observations and is always advisable, if only as a guide to the best position and locality for subsequent exposures.

Before attempting to view the radioscopic image, the observer should close his eyes or remain in complete darkness

for a few minutes, and the tube box diaphragm, preferably with a rectangular opening, should be contracted on each small area inspected.

This reduction of the diaphragm opening will serve the purpose of protecting the observer from penetrating rays, as well as producing a better contrast on the portion of screen under observation.

Radiography.—Apart from the movements, the appearances on a screen or radiogram are similar, but are more conveniently and precisely observed on the permanent record. From the thickness of the part there is necessarily a considerable distance between the sensitive plate and some of the parts casting shadows upon it. Thus, the record obtained in a radiogram is a considerably distorted view of the parts in question; and since the various organs lie at different levels, their relations are somewhat distorted also. This is more fully discussed in the chapter on "Orthodiagraphy," which is a method devised to obviate the distortion mentioned. The fact of distortion must always be borne in mind in thoracic diagnosis, and it has doubtless much influence in causing the uncertainty mentioned at the beginning of this section.

If a radiogram be desired to show the *heart* plainly, the plate should be placed *in front* (see Fig. 332). If it be more particularly desired to view the *lung apices*, the plate should be placed *behind*, but for a *general view* of the lungs the latter position is not so good, since the heart, in its nearer position to the source of the divergent rays, throws an enlarged shadow which obscures a considerable portion of the field. This may be partially obviated by setting the tube at a greater distance, as explained under the heading of *Teleradiography*, on page 185, but this is not always convenient. As to the relative advantages of the erect or prone position of the patient, there is variety of opinion; but, provided that the radiograms are contrasted with the proper normal appearance for the position employed, there is not much to choose between the views obtained. For screen work the patient should preferably be viewed in the erect position, but for radiography, except in special cases, the prone position is commended by its convenience.

For the erect position a patient may either sit or stand, as may be convenient or dictated by his condition. A special procedure for viewing apices of the lungs alone is described on

Fig. 332.—Normal Thorax, Plate in Front.

Plate XLVII.

page 385. For a general view the patient should lie on his face or stand bending over the end of the table, with his chin beyond the further edge of the exposure cassette, and his anterior chest wall pressed closely down on the cassette. His arms clasped round the edges of the table will assist immobility during exposures, which should be made at the instant of complete inspiration. Respiration should be inhibited during exposure, which may be made very brief by use of double-sided films with two intensifying screens, as described on page 184.

In Fig. 332 is reproduced a radiogram of a normal thorax, the plate having been placed in front and the X-ray tube behind. This is seen to consist of a light area, corresponding to transradiant lung on either side, the two sides being separated by a dark "*median shadow.*" This *median shadow* is cast collectively by the vertebral column, the sternum, and the heart with the great vessels attached to its base. The *right border* is almost vertical, with a slight angular deflection outwards below its middle. It is made up from above downwards by the *spine*, the *vena cava superior*, and, under the obtuse angle, the *right auricle*, the shadow of which joins that of the diaphragm or liver.

It is a general and useful convention to consider that this right border should not, under normal conditions, be at any point more than ½ in. from the line of the right border of the sternum.

The *left border* is vertical in its upper part, which is either straight or with a slight convexity outwards, and corresponds to the *spine*, the *aortic arch*, and the first part of the *descending aorta.* From its occasional convexity this part is spoken of as the "left lateral aortic bulge," and is more definitely viewed with the screen or plate placed behind, whilst its constituent parts may be differentiated by rotating the patient, under observation, into the oblique position described on page 422. This is followed by a more marked convexity formed by the left *pulmonary artery*, and part of the *right ventricle.* Sloping slightly outwards, this second part joins more or less abruptly a larger convexity, which lies diagonally and is formed by the *left ventricle.* This in turn joins the shadow of the left diaphragm and liver (see also Fig. 363, on page 416).

The "median shadow" is more fully discussed in dealing

with diagnosis of abnormal conditions of the heart and great vessels (page 416), and its more exact observation is described in the following chapter on "Orthodiagraphy."

At each junction of the cardiac shadow with that of the diaphragm may be seen on deep inspiration a triangular space called the "cardio-phrenic space." This is well seen on the screen, but may be blurred by movements during exposure for a radiogram; in occasional cases it is seen to extend right across between heart and diaphragm.

At each end of the diaphragm shadow is also an important triangle, which may be illuminated only on deep inspiration. The importance of this is discussed, in relation to the presence of fluid in the pleural cavity, on page 391.

LUNGS.

Normal lung tissue may for practical purposes be considered completely transradiant, especially at the end of inspiration; thus, each "*lung field*" should normally be represented by a uniform clear area crossed by shadows of the superimposed ribs and by a number of shadows, normally faint, produced by anatomical structures situated at the root of each lung and radiating thence towards all parts of the lung.

Around the cardiac shadow certain faint lines or streaks, more pronounced on the right side, are probably due to folds of pericardium at the junction of that structure with the parietal pleura, but the more definite cresent-shaped "*hilum shadow*" opposite the second costo-sternal junction with strands radiating towards the peripheral parts, is doubtless due to the combined effect of the bronchi and larger pulmonary vessels with their branches and the accompanying lymphatics and connective tissue. The appearance must be known and noted as normal, or it may be mistaken for an indication of pathological change.

From the opposite diagram, Fig. 333, reproduced by kind permission from Overend's "Radiography of the Chest," the composition of this shadow may be understood, and from Fig. 332 its appearance in the radiogram of a normal thorax may be noted.

In health, and especially before 15 years of age, this hilum shadow and its radial extensions should be faint or invisible; in later years its intensity will depend upon the impurities of the atmosphere which the patient is accustomed to breathe. Amongst adult dwellers in smoky towns it will be clearly

marked, whilst in miners and stone workers its intensity will suggest, and border upon, a pathological state.

Normally, the central denser area of shadow extends along each side of the median shadow between the anterior ends of the second and fourth ribs, corresponding posteriorly to the vertebral ends of the sixth and eighth ribs, and should not extend laterally beyond the junction of the cartilaginous and bony parts of the ribs.

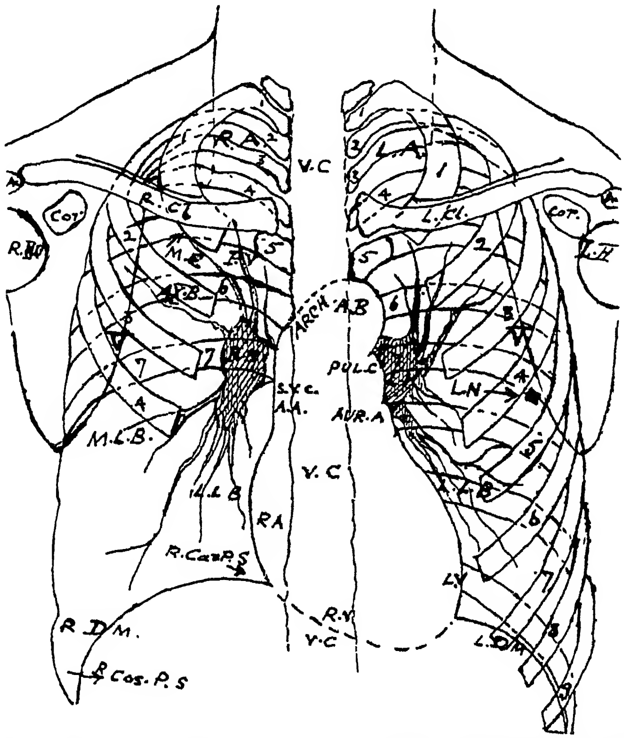


Fig. 333.—Anterior View of Chest—Lower Right Ribs Removed.

On the left side the crescentic hilum shadow is more or less eclipsed by the median shadow, whilst on the right side a clear space is usually visible in health between the crescent and the adjoining border of the median shadow.

The linear extensions towards, but not reaching, the periphery form a so-called "pulmonary reticulum," due to the smaller bronchi and bronchioles with their accompanying structures, and, like the central areas, the shadow produced may vary much in intensity, so that normal limits are hard to define.

In this connection the following conclusions of the X-ray Division of the Committee on Medical Research of the National Tuberculosis Association of America, published May, 1922, are of interest:—

Conclusions of the X-Ray Division of the Committee.

The Normal Chest.—The normal chest of the child, from the roentgenologic standpoint, is subject to such wide variations within normal limits as to be beyond the possibility of exact description.

Hilum Shadow.—The conglomerate shadow, commonly called the hilum shadow, when found lying entirely within the inner third or zone of the lung area, can be disregarded (or regarded as normal), except where it is made up of a solid mass of homogeneous shadow giving undoubted evidence that it represents a growth or mediastinal pleurisy.

Calcified Nodes.—Calcified nodes at the root of the lung, without evidence of lung disease, are of no significance except as a possible evidence of some healed inflammatory condition, possibly but not necessarily tuberculous. They are a common finding in normal chests.

Density and Thickness of Trunk Shadows.—In the normal lung the bronchial trunk shadows are not visible in the extreme apical regions. For convenience of description the remainder of the lung is divided into three vertical zones, extending outward from the lateral border of the spinal shadow to the lateral chest border.

The inner zone contains the root shadows.

The mid zone contains the trunk shadows, gradually fading out into their final subdivisions.

The peripheral zone contains lines radiating from these and fading off before the periphery is reached.

Where, in the mid zone or peripheral zone, these shadows do not disappear in the characteristic fashion described, the appearance may be evidence of a variety of conditions, past or present, of an inflammatory nature or otherwise. It may accompany a tuberculous process but it is not necessarily indicative of tuberculosis.

Improper or Misleading Terms.—The use of the term "peribronchial tuberculosis" and "parenchyma tuberculosis" is not to be recommended in the interpretation of roentgenograms of the chest. Until corroborated by laboratory or clinical findings, the use of the terms "active" and "quiescent" should not be definitely applied to evident lesions demonstrated on plates.

Diaphragm.—The arched shadow forming the lower limit of the thorax is usually spoken of as the *diaphragm shadow*, though really produced mainly by the underlying liver. It is normally a little higher on the right side than on the left, and is seen to move up and down with a piston-like movement synchronous with respiration. Under normal conditions the excursions are approximately equal on the two sides in quiet respiration, and measure about ½ to ¾ in. vertically. In forced respiration the left side tends to shew slightly greater move-

ment than the right, but where marked inequality is noted in ordinary respiration the condition is pathological.

Thus, when one side is affected by tuberculosis, there is, in the majority of cases, a perceptible diminution of the excursion on that side, and the movement may further be jerky and interrupted or undulatory. This diminution of excursion of the diaphragm on the affected side is an early sign of phthisis, and from its presence tubercular affection of a lung may be diagnosed, while physical signs are still in doubt. This is further discussed on page 399. The dome-like shadow of the

Fig. 334.—ADHESION OF RIGHT DIAPHRAGM.

diaphragm may shew irregularities of its surface, the most usual being triangular in shape, as produced by pleural adhesions, and as seen in Fig. 334.

To note the lesser degrees of difference in movement of the two sides, the limits of excursion should be marked on a piece of glass or paper laid on the fluorescent screen, while that is held steadily in position. The degrees of excursion, as measured by the distance between the marks on either side, can then be accurately compared and inferences drawn, but visual inspection will usually suffice. Pain in some region under the diaphragm may inhibit its movements. This inhibition may disappear on deeper respiration. The whole significance of diaphragmatic movements is still somewhat unsettled. In any case of doubt

the radiographer need only note the observed facts and leave the physician to make his inferences.

Reverse movements may be noted in certain cases associated with unilateral phrenic paralysis, congenital or otherwise, or with diaphragmatic hernia. The radiographic appearance in such cases will be found described and illustrated on page 415.

Sub-diaphragmatic abscess will shew a marked elevation of the diaphragm, and movement will be abolished or very limited. In the absence of fluid above the diaphragm, this condition will usually be recognisable from the constancy of the clean-cut shadow in various positions. A gas bubble in the abscess may permit alteration of the pus level, when the diaphragm outline must be looked for. Presence of fluid above the diaphragm may complicate the diagnosis, and if that fluid be encysted between the base of the lung and the diaphragm, differentiation will be difficult if not impossible. (See further notes on page 391.)

Apices.—During *deep inspiration* the lungs are seen to become more transradiant, the effect being due jointly to the greater amount of contained air and to the lessened amount of blood in the capillaries.

While being viewed with the screen, the patient should be instructed to breathe somewhat deeply. In light inspiration a dulness may be noted in one or both apices, suggestive of tubercular deposit, but on deeper inspiration this may clear up, proving the dulness to have been due merely to lack of expansion. The effect of coughing should also be observed, as opacities due to temporarily lodged secretion may thus be cleared.

For observation of the apices the posterior position of screen or sensitive plate may be preferable, but a good view may be obtained with screen in front, although the clavicle and first rib definitely limit the area.

In viewing and comparing the apices critically, the current should be cut down to a minimum and the diaphragm opening contracted to a very small area.

Ribs.—The *position and movements of the ribs* should also be noted and compared on the two sides. Impaired movement is suggestive of mischief on that side, as also is abnormal position.

Abnormal *distension* of the thorax, as by pneumothorax (Fig. 342), or emphysema (Fig. 343), produces a more nearly *horizontal* position; whilst *collapse* of the lung induces a more

dependent position of the arched portion of the ribs, giving an appearance like overlapping *roof tiles* (see Fig. 345).

In all examinations much depends upon comparison of the two sides of the thorax; hence care must be exercised to see that the two sides are equally illuminated, and that by a tube just hard enough to illuminate the screen.

Further points may be elicited more conveniently from a radiogram, though most of them are discernible also on a fluorescent screen suitably illuminated.

Radiograms, to be of any value for comparative diagnosis, must be taken in standard positions (except for special purposes), and at a standard distance.

For a *general view* with the tube in front, that should be set centrally at the level of the fourth costal cartilage; with the tube behind, it should be set opposite the spine of the fifth dorsal vertebra.

For a clear view of the *apices* alone the tube should be centred over the middle line in front, and set at about the level of the chin, while the head is tilted slightly backwards. This throws the shadow of the clavicles downwards and clears the second and third intercostal spaces posteriorly.

The area in the neighbourhood of the inner end of the clavicle, where it joins with the sternum, should receive special attention in all inspections.

The apex region is bounded in front by the line of the clavicle and is crossed by the first rib, the presence of which, with its transverse clouding shadow and its curved outline, should always be remembered.

The thorax, for purposes of examination and report, should be considered as divided into regions bounded by lines marked by constant landmarks; indication of localities by reference to different lobes of lung, or to interlobular fissures, is often very indefinite. Fig. 335, on following page, shews diagramatically suitable boundaries for reference areas.

The *apex* or *supraclavicular area* is bounded by the clavicle, or may be quoted as bounded by a horizontal line at the level of the vertebral end of the fourth rib.

A *basal* area is bounded below by the diaphragm, and above by a line drawn from the vertebral end of the eighth rib parallel to the posterior course of that rib.

The *mid portion* is subdivided by a line drawn from between the vertebral ends of the seventh and eighth ribs diagonally

upwards to the axilla, to meet there the horizontal line from the vertebral end of the fourth rib, which forms the lower boundary of the apex. Vertical lines drawn on each side of the vertebræ over the heads of the ribs form, with the two lines mentioned, two *paravertebral triangles*, also known as *subclavicular* or *sub-apical*, which triangles are of great importance in inspections for adult phthisis.

The lower portion of the middle area, known as the *wings* or *middle triangles*, contains the hilum of each lung, and is of special importance in inspections for early signs of perihilar or miliary tuberculosis, or in broncho-pneumonia.

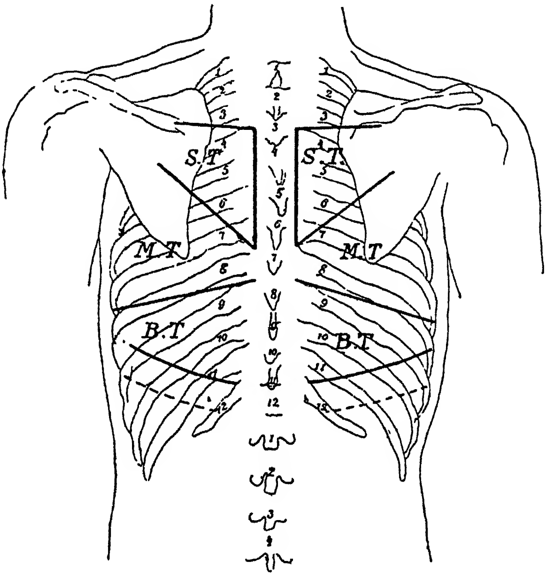


Fig. 335.—Reference Areas of Thorax.

An alternative scheme of reference may be employed by considering the thorax divided into three regions by two horizontal lines across its front, one at the level of the second rib, and one at the level of the fourth.

The normal appearances of each area must be carefully studied under various conditions, as the diagnosis of disease may depend upon slight alterations in those appearances, such alterations at times consisting merely of accentuation of normal features.

Thus, an *increased distinctness of the bronchial markings* leading to the "pulmonary reticulum" will suggest some fibrosis following infection or the penetration of a new growth,

whilst *accentuation* and possibly *broadening* of the *hilum shadow* will suggest early tuberculosis or one of the other conditions affecting the structures producing that shadow.

The transradiancy of an *apex* may be interfered with by thickened pleura, the *diffuse* effect of which may be simulated by an overlying enlarged thyroid, whilst a more or less discrete *mottling* will suggest early phthisis. Lower down in the chest a confusing haze may be produced by the female breast, whilst even a male nipple may occasionally, with a soft tube, leave its record on a plate set on the front of the chest.

It is not always easy, and sometimes impossible, from X-ray evidence alone to indicate precisely the condition responsible for appearances noted, since several conditions may produce similar appearances, but consideration of various points will often make such differentiation possible. These points are indicated in the notes of reference to the subsequent series of illustrations of various lung conditions commonly met with. Before considering the actual illustrations, the relations of some appearances found to the conditions producing them are suggested in the following table. This makes no pretence to be exhaustive, but is intended to be suggestive, and the reader may readily supplement it from his clinical experience:—

- Diminution of transradiancy suggests
  - diffuse
    - **consolidation.**
    - **bronchial stenosis.**
    - **thickened pleura.**
    - **fluid in recumbent position.**
  - in irregular patches
    - especially at apices, **phthisis pulmonalis.**
    - especially at bases, **congestion.**
    - **broncho-pneumonia.**
    - **fibrosis.**
    - **new growth.**
  - in delimited patches
    - **encysted pleural effusion or empyema.**
    - **hydatid cyst.**
    - **new growth.**
    - **abscess.**
    - at apices, **phthisis pulmonalis.**
    - at bases
      - **œdema.**
      - **pleurisy.**
      - **empyema.**
      - **bronchiectasis with secretion.**
    - at root
      - **hilum tuberculosis.**
      - **pneumonia (commencing or receding).**
      - **enlarged bronchial glands.**
- Increase of transradiancy suggests
  - in patches
    - **bronchiectasis.**
    - **phthisical cavities (empty).**
  - general
    - **emphysema.**
    - **pneumo-thorax (with shadow of contracted lung).**

Pleurisy.—It will be readily understood that any thickening of the pleura, or presence of fluid in the pleural cavity, must markedly alter the appearance of the part affected as viewed by X rays.

Acute pleurisy without effusion causes no alteration in appearance, but the *excursion of the diaphragm* and movement of ribs will probably be affected; the importance of the use of the screen in all thoracic examinations is here borne out.

Thickened pleura will cast a *shadow by contrast* with the unaffected parts, though not so dense as when fluid is present. The shadow will be more diffuse and less definitely limited, whilst the absence of displacement of the heart may assist differentiation from the latter condition. Excursion of the diaphragm may be affected.

Consolidation of the lung (see page 392) may cast a similar shadow, but will also by contrast shew change in breadth of the affected side, producing the change in position of the ribs known as roof-tile, which is absent in a case of thickened pleura.

Interlobar thickening of pleura may be noted by a more or less dense shadow localised about an interlobar fissure. (Fig. 337.)

Effusion of fluid into the pleural cavity produces changes in appearance not readily missed or mistaken, whilst the thorax is vertical and the fluid is not encysted. A *homogeneous shadow* is cast, more or less dense according to the amount of fluid present, and also according to the nature of the fluid. Thus, pus casts a denser shadow than serous fluid of the same amount, but the comparison is somewhat indefinite.

With serous effusion or empyema, without the additional presence of air, the masking shadow decreases in intensity from below upwards, and its upper margin is ill defined, especially if the lung above be compressed or consolidated, in which latter case no differentiation may be possible.

With no such complicating condition of the lung the *upper limit* of the fluid, as seen in the shadow, is usually *concave*, due doubtless to the action of capillarity, the concavity being less according to the amount of fluid present, and the shadow usually appears higher at the axillary end, as seen in Fig. 338. Normal lung above this line appears very clear by contrast. *Displacement of the heart* is usually well seen, this being to the opposite side to the effusion, in contrast to a case of *solid lung*, in which displacement will be towards the same side. A

Fig. 336.—THICKENED PLEURA.

Fig. 337.—INTERLOBAR PLEURISY.

Plate XLVIII.

Fig. 338.—PLEURISY WITH EFFUSION.

Fig. 339.—PNEUMOTHORAX.

Plate XLIX.

further differentiating sign may be found if the patient's position be altered, when, if fluid be present, the level will be seen to alter. This sign will be more marked if any air be present above the fluid, and disturbance of the surface line of the fluid may be noticed if the patient be shaken. Probably the earliest definite evidence of the presence of fluid is obtained by noting the *triangle at the outer end of the diaphragm shadow* where it joins the chest wall. This is not occupied by lung unless on very deep inspiration; hence consolidated lung can never obliterate it, but fluid will early flow into it and produce a marked change in the appearance.

Between serous fluid and pus, X-ray examination does not make exact differentiation easy, since the difference in shadow is wholly one of degree.

In the prone position free fluid will spread over the lung tissue, so that it appears like thickened pleura.

A serous effusion or empyema when *encysted* may be difficult to differentiate from an abscess or new growth. Such encysted fluid may appear in an interlobar fissure, against the chest wall or at the base of a lung. Differentiation from *intra-pulmonary conditions* may be materially assisted by viewing the chest in various positions and, further, by stereoscopic views; but the *general haze* produced by pleural conditions usually contrasts with the *mottled* appearance of the former.

Pneumothorax will present an appearance strongly contrasting with pleurisy, since here the affected part will be *abnormally transradiant*, as seen in Figs. 339 and 340. The lung, if free from adhesions, may be represented only by a dense stumpy shadow in the region of the hilum, but more commonly, especially in tuberculosis, complete collapse of the lung will be prevented by adhesions binding its periphery to the chest walls, as in Fig. 339.

Absence of respiratory movements of the chest wall will be marked, as also will *displacement of the heart* to the opposite side.

The condition will be differentiated from *emphysema* by the shadow of the collapsed lung, with its sharply defined margins, and the absence in the transradiant area of any lung markings.

The production of *artificial pneumothorax* in certain classes of phthisis furnishes a new sphere of usefulness for radioscopy; and, where its complete production necessitates severance of interfering adhesions, the performance of that operation may be simplified and rendered precise under screen observation.

Fig. 341 illustrates a case of artificial pneumothorax.

Hydro- or **Pyo-pneumothorax** combines the appearances of the two conditions just described. The *upper level* of the dense shadow cast by the pus is *sharply defined*, and is unvaryingly *horizontal*, as seen in Fig. 342, in contrast with the concave margin noted in pleurisy.

If the patient's position be altered, this upper limit is seen to maintain its horizontal position, and if the patient be shaken, movements like splashing may be distinctly evident on the surface of the fluid.

Pneumonia casts a shadow varying with the stage of the disease. The density of shadow will naturally vary with the degree of consolidation, and it is interesting to note that normal transradiancy is not regained by the affected lung till some time after convalescence is established. Points of differentiation from pleuritic affections have been already noted. In cases of central origin, where percussion may fail to detect early conditions, X-ray examination is especially useful. There is not opportunity to examine many such cases; but observations tend to bear out the suggestion that all pneumonias are really central in their origin, progressing from the root of the lung towards the more superficial parts, in which ordinary physical examination may more readily determine their presence.

Emphysema produces appearances directly opposite to pneumonia, just as it produces opposite physical signs. The affected areas are rendered *more transradiant* and more extensive, as seen in Fig. 343; while *interposed objects*, such as the ribs and heart, have their shadows very *sharply defined*. The *ribs* are seen to assume a more or less *horizontal* position, and to have *little movement* even on deep inspiration. The diaphragm on the affected side is displaced downwards, and has its ordinary movement restricted. The heart, too, is displaced downwards, and assumes a more vertical position—hung, as it were, by the vessels attached to its base.

Accompanying conditions, such as caseating patches, are often impossible of detection by percussion owing to emphysema, but in X-ray examination their detection is made easier by the increased contrast of that condition.

The appearance of such patches or other *lung markings* in the transradiant area differentiate this condition from *pneumothorax*.

Fig. 340.—PARTIAL PNEUMOTHORAX.

Fig. 341.—ARTIFICIAL PNEUMOTHORAX

Fig. 342.—PYO-PNEUMOTHORAX.

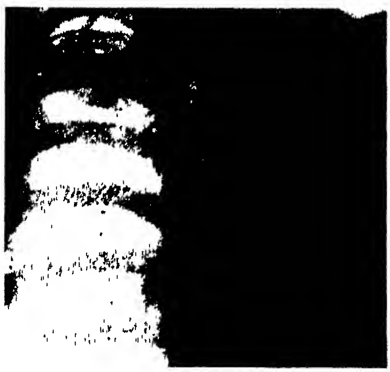


Fig. 343.—EMPHYSEMA.

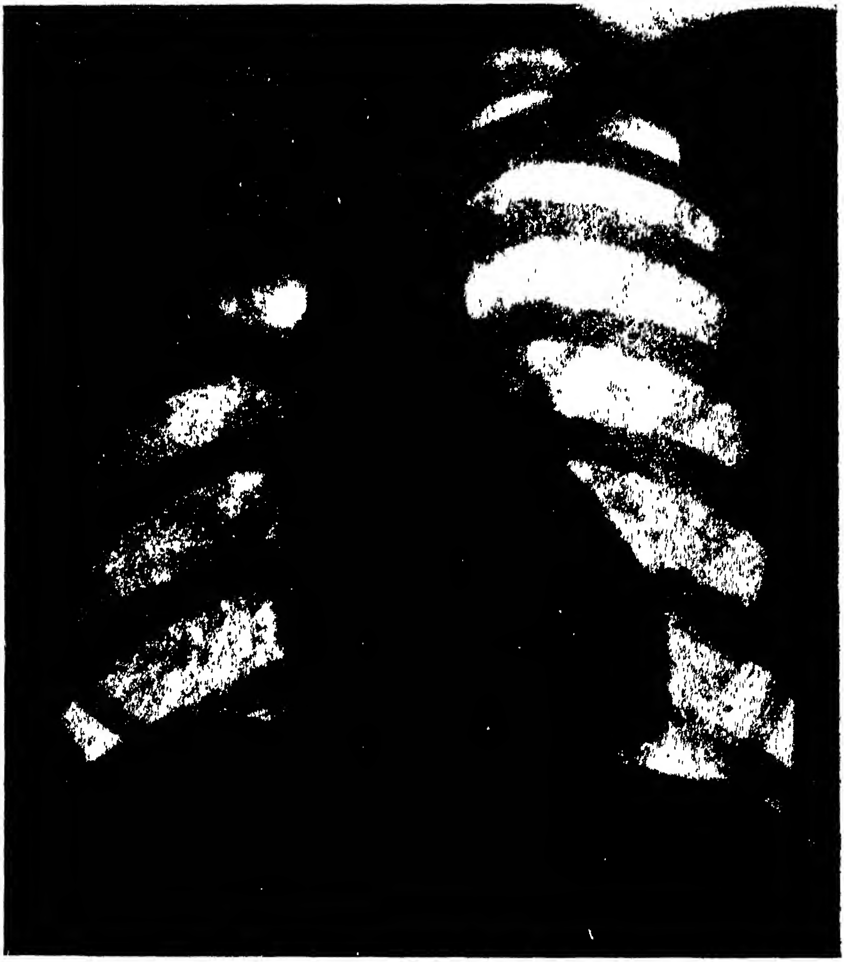


Fig. 344—ACTIVE PULMONARY TUBERCULOSIS.

P'ate LI.

Pulmonary tuberculosis lends great opportunity for the radiologist who combines clinical experience with his radiology.

For evidence of early conditions X-ray examination is most useful, although, as a general rule, it cannot be relied upon apart from a knowledge of other conditions present or possible in each case. To confirm, or to differentiate, other ascertained physical signs it is, however, an indispensable auxiliary in diagnosis, as discussed earlier on page 373. Certain other conditions may closely simulate some of the appearances about to be described as evidence of phthisis, but seldom, if ever, will the combined appearances ascribed to that be produced by any other condition. Recent apical pneumonia, or pulmonary embolism and infarction with mitral stenosis, are examples of possible pitfalls, but the history and accompanying signs should enable a careful radiologist to steer clear of them.

Such history and signs must, however, always be taken note of, and, if any doubt exists, a second examination should be made after an interval of some days or weeks before a definite opinion is expressed.

Negative evidence in a suspected case is very valuable as indicating absence of disease, and in this way X-ray examination may be of even more value than when signs—mayhap indefinite—are found.

Fig. 344 opposite reproduces the appearances found in a typical case of active pulmonary tuberculosis affecting chiefly the right apex and the middle region of the right lung.

Most of the signs described in the following sections as assisting in the diagnosis of phthisis will be found in this figure more or less distinctly, but in later pages further radiograms are reproduced, which illustrate more graphically certain special points dealt with in the adjoining text.

In a case of tuberculosis of the lung various points may be noted.

(1) *Change in form of the chest*, due to limited expansion, may be evident. Apart from dimensions, attention may be arrested by the change in *position of the ribs*, which assume an appearance of overlapping each other, hence termed "roof-tile," as seen in the right side of Fig. 345. This is, however, a late change, and usually where present the case will already have been diagnosed by other means.

(2) The appearance of *patchy or mottled shading* in the areas normally transradiant and clear is very characteristic, and varies in amount and intensity according to the extent of disease present.

This shading is produced by diseased portions of the lung tissue, *calcified* patches casting the most dense, *caseous* patches less dense, and *grey and yellow tubercles* still less dense, but quite definite, shadows.

Fig. 346 opposite represents well the woolly appearance of this mottling in a case of disseminated phthisis. *Before physical signs* are evident diseased patches may be detected by this mottled shading; and frequently when a case is referred with suspicion of tubercle in one apex, this evidence will be discovered in the other apex as well, though by physical signs that may be quite unsuspected.

Where there is *accompanying emphysema* masking the physical signs of such condition, and causing percussion to fail absolutely in its detection, an X-ray examination is particularly useful, since the appearances described above are rendered *more distinct by contrast* with the clearer areas of emphysema.

(3) As mentioned earlier, the *apical appearances* should always be checked on the screen by causing the patient to inspire deeply, since a partial and suspicious dulness may thus be entirely cleared up, and possibility of error in diagnosis lessened. If one or both apices refuse so to clear up, strong evidence is furnished of a tubercular condition, the stage of which must be judged from the presence and extent of accompanying conditions

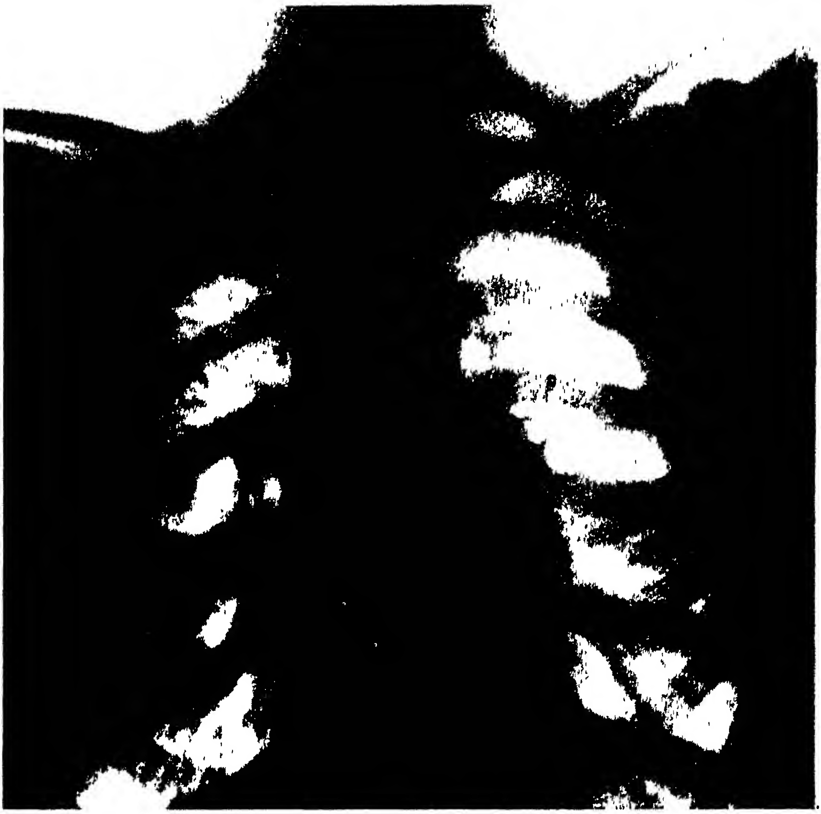


Fig. 345.—"Roof-tile" Ribs.

Fig. 346.—Disseminated Nodal Tuberculosis.

Plate LII.

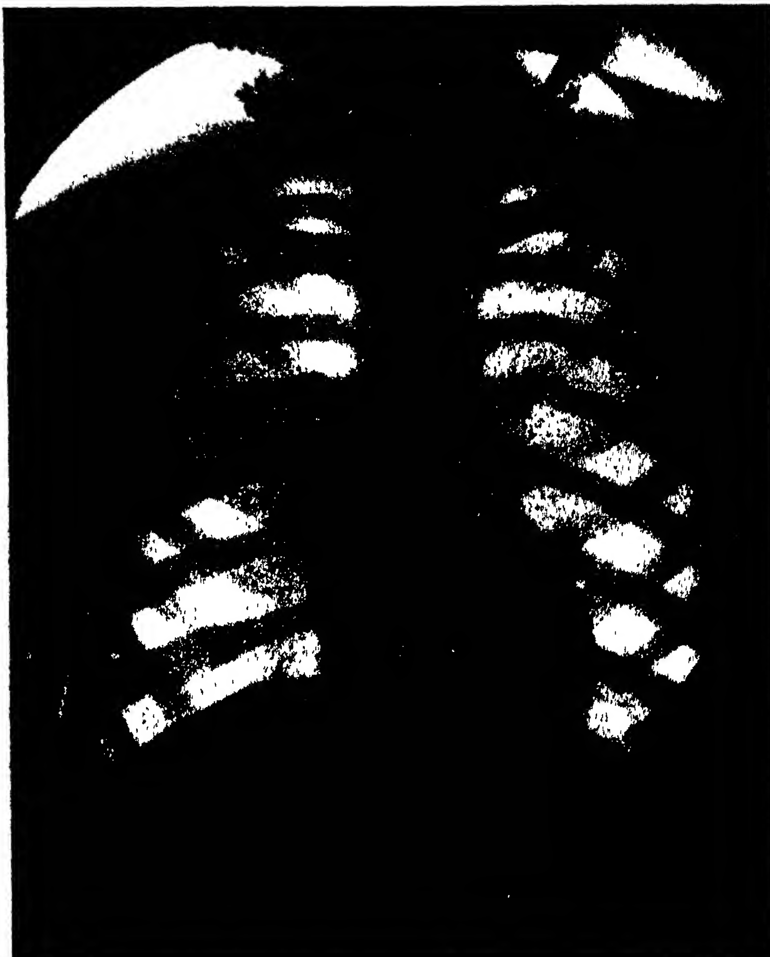


Fig. 347.—Hilum Tuberculosis—Limited.

Plate LIII.

4. *Movement of the diaphragm shadow* is a valuable and most interesting observation to make relative to a query regarding presence of tubercular disease of the lungs. From the nature of the sign it can only be observed on the fluorescent screen, and it should be so observed and measured with the screen situate on the anterior and posterior aspect in turn.

In the normal thorax the movement on each side is practically similar in nature and degree, though commonly the excursion on the left side is slightly greater than on the right. On the side affected with tubercle, however, the movement, as described on page 383, is usually restricted, and may be jerky, interrupted, or undulatory in character. This may amount almost to fixation of that side of the diaphragm, but it is from the less-marked degrees of restriction that assistance is looked for in early diagnosis. These may be detected by measuring as described in the section above referred to, and the observation should never be neglected in cases offering the least suggestion or suspicion of phthisis.

The absence of such restriction of movement is not, however, to be relied upon as a negative sign indicating freedom from disease. In early apical tuberculosis the diaphragm movements may show no modification, whilst other signs give unmistakable evidence of disease.

(5) *The position and form of the heart* is described by some observers as typical in cases of phthisis, but variations are too common to admit definite classification of a type.

The cardiac shadow is doubtless, in the majority of early and acute cases, smaller and more vertical than usual, but how much of this change in size is due to rotation is not defined. In chronic cases the heart may appear large and bulbous. Thus, a small-sized heart has been said to predispose to tuberculosis, whilst a large heart justifies a more hopeful prognosis. This is an interesting point, but one requiring considerable elucidation before dogmatic statements can be accepted upon it.

"*Hilum Tuberculosis*" has come to be recognised as a definite clinical entity, as a result mainly of radiological observations correlated with clinical symptoms, but such correlation is indispensable before any definite opinion may be expressed. A case of this nature, as in Fig. 347, first shews an *increase* in *extent* and *density* of the *hilum shadow* described on page 380, and this may be irregular in shape on account of enlarged root glands. This is followed by a general thickening and increase in density of the *radial bronchial markings*, along the course of which bead-like swellings appear in the shadow outlines; and the picture is completed by roughly triangular areas of hazy density with bases towards the *peripheral parts* of the lung.

The *mottled* shadows already described then appear in the "lung fields," and the appearance of those woolly patches justifies a *definite diagnosis* of active tuberculosis, especially if it is accompanied by narrowing and lessened expansion at the apices. Fig. 348 shews such a case, and the appearances may be noted also in Fig. 345.

A *similar increase* of the hilum shadow and bronchial markings may follow *other lung infections* such as pneumonia, measles, pertussis and bronchitis, or the irritation of *dust inhalation*, since gland enlargement and some degree of fibrosis are common to those conditions, but other characteristic signs of tuberculosis will be missing and the clinical history will usually differentiate clearly.

In children under 15 definite enlargement and increased density of the hilum shadows are always strongly suggestive of tuberculosis, but care must be exercised, as mentioned above, in ascribing a cause for such appearances.

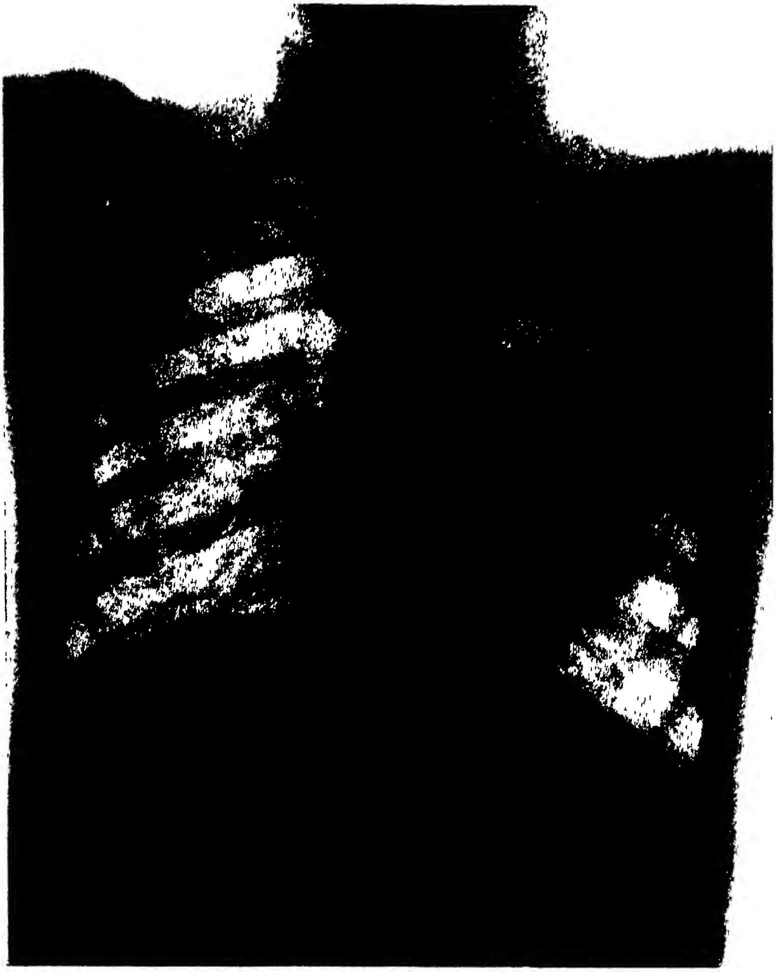


Fig. 348.—Hilum Tuberculosis—Extending.

Plate LIV.

Fig. 349.—Cavity in Each Axillary Region.

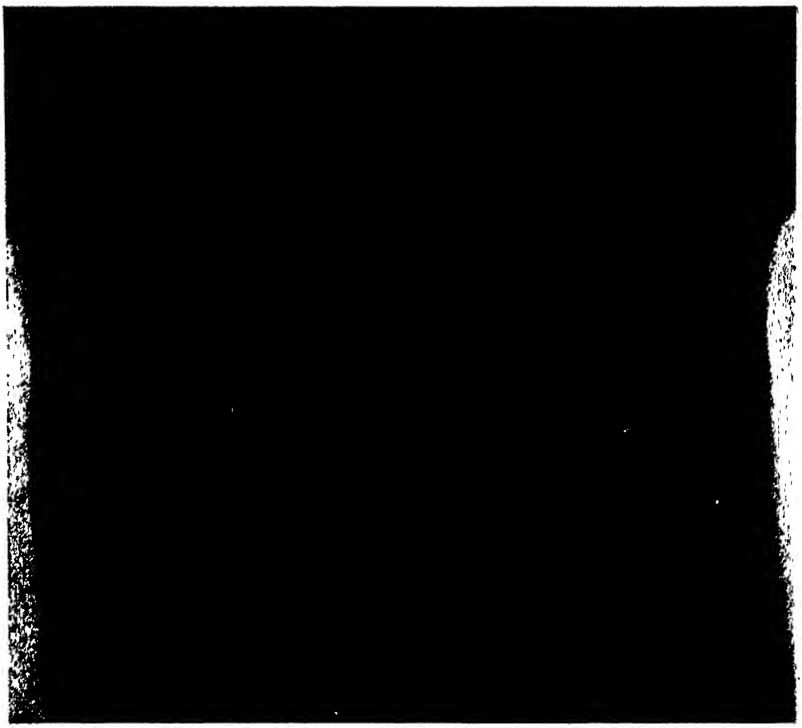


Fig. 350.—Miliary Tuberculosis.

Cavities in the lung are usually clearly definable by X rays. If air-filled, they present a clear area, similar to, or less dense than, normal lung and surrounded by a dark ring of shadow, produced by surrounding consolidation. If filled with pus, the shadow is dark throughout, and detection of the cavity less certain, and its appearance may be obscured by superposed dense tissue. Clearness of definition will naturally depend upon the position of the cavity relative to the sensitive plate, and stereoscopic views may be very useful for more precise location. Fig. 349 shews a cavity in each axillary region. That on the left side suggests the necessity to exercise caution in differentiating from "pleural rings," which are of similar appearance but are probably produced by superficial areas of adherent pleura.

Early signs of tuberculosis in the lungs are found most commonly in the apices in the paravertebral triangles (described on page 386), below the inner third of the clavicle, or immediately outside the normal hilum shadow.

Active disease is indicated by a fine mottling, produced by numerous small opacities with ill defined *fluffy margins*, which appear like halos around the greyish opacities, the whole giving a "woolly" appearance to the area affected (see Fig. 346). *Spread* is indicated by increase of this area, and degree of *activity* may be roughly measured by the number of opaque centres in a given space.

Miliary tuberculosis is characterised by a very fine mottling scattered throughout the lung fields, as seen in Fig. 350. The foci, if separately distinguishable, are seen to be of very small size—or the whole field may be obscured, as by a diffuse opacity due to the superimposed layers of foci at all depths of the lung tissue.

Chronic disease is indicated by denser and larger centres of opacity, with *more definite outline*, separated by emphysematous patches and *patches of finer mottling*. Bronchial markings are more distinct and cavities, if present, will be sharply outlined, whilst other signs of fibrosis may be evident along with changes in form of the chest. Fig. 351 opposite represents such a case.

Arrest and healing are indicated by dense opacities with clear-cut outlines, and by distinct strands of fibrosis separated by clear emphysematous areas, but *without any mottling* or "woolliness."

Enlarged glands at the hilum and in the paravertebral triangle will appear dense and clearly outlined, and later calcification will make those very prominent in a radiogram, as in Fig. 352.

Those signs of healing may appear at one part of a lung whilst evidence of progress appears at another, so that it is often very hard to say from X-ray evidence alone whether a case is active or quiescent.

Broadly, however, it may be taken that greater clearness of the general field and distinctness of detail denotes less activity, whilst loss of pattern with general obscurity of field suggests greater activity.

Fibrosis of the lung appears, in greater or less degree, in chronic disease, as on the right side, and at the left base, in Fig. 351. This also appears in repair after acute attacks, and has been referred to in preceding sections. The appearances may be those of *exaggerated* density and distinctness of the *hilar and bronchial shadows*, already noted in acute and chronic disease, or further effects may be produced by *bronchial stenosis* and contraction of tissues. The affected part then casts a dense shadow, generally uniform in character. There will be collapse of the chest wall, with more or less distortion and roof-tile appearance of the ribs, and the *heart shadow* will be seen *displaced* towards the affected side.

This displacement differentiates the condition from *fluid* in the pleural cavity, which may cause a similar uniform dense shadow. If the fibrotic condition be definitely *unilateral*, displacement of the mediastinum towards the affected side may be noted during deep inspiration.

Fig. 351.—Chronic Pulmonary Tuberculosis.

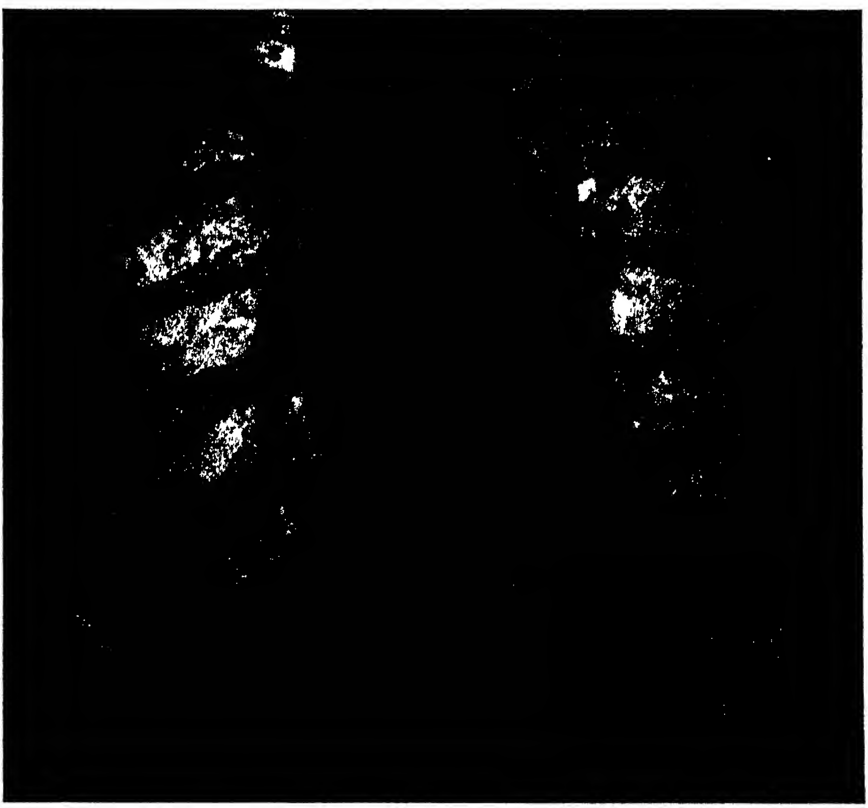


Fig. 352.—Calcification of Old Diseased Areas.

Plate LVI.

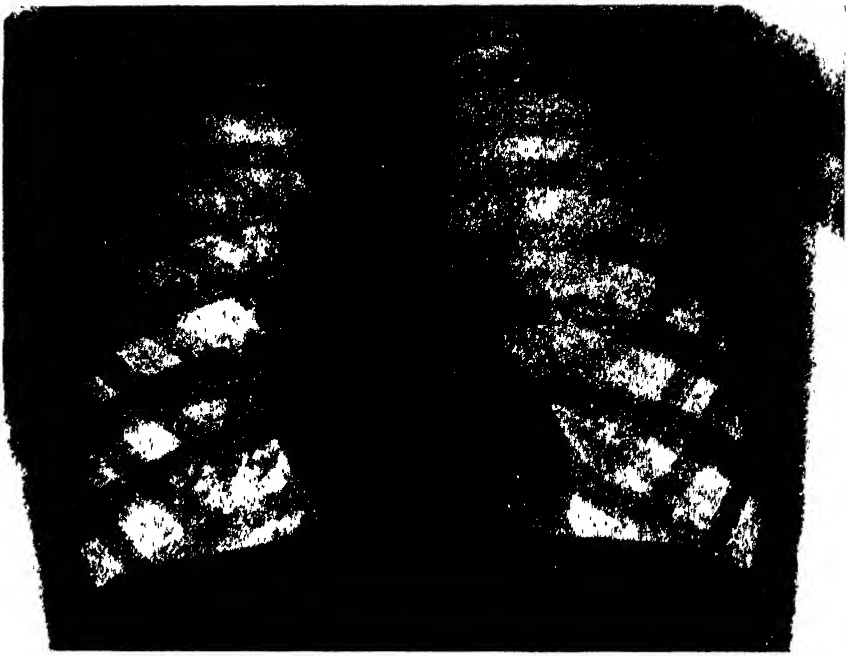


Fig. 353.—CHRONIC BRONCHITIS.

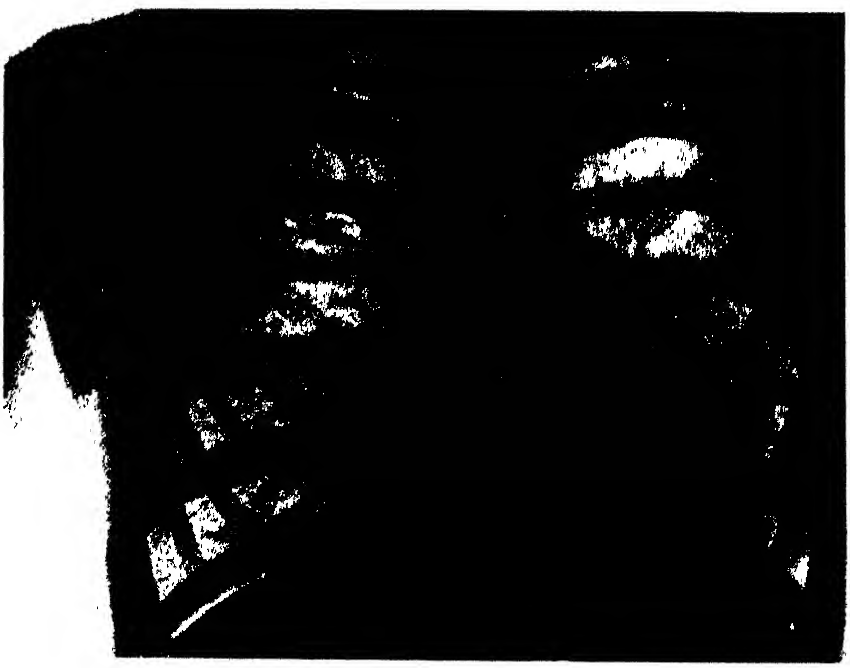


Fig. 354.—CHRONIC BRONCHITIS.

Plate LVII.

Simple catarrhal conditions of the lungs are differentiated from tuberculosis by the absence of infiltration or consolidation of the lung tissue, those conditions being detected by the appearance of mottling already described.

Chronic Bronchitis may produce *increase* in size and density of the *hilar* and *bronchial markings* and glands, as seen in Figs. 353 and 354, but *none* of the other characteristic signs of tuberculosis in the *lung tissue*.

Bronchiectasis will shew *further increase* in size and density of the structural markings in the lung, with occasional ring-shaped shadows of thickened and dilated bronchi. Those appearances will usually be accompanied by appearances of definite *cavities*, but the details of the picture will in many cases be more or less obscured by the dense infiltrated lung tissue surrounding the bronchi, and by the muco-purulent contents of the dilatations and cavities. If those contents be evacuated a striking and instructive change may be noted in a subsequent radiogram.

Abscess in the lung will evince its presence by a dark shadow more or less definitely circumscribed. An abscess cavity may, however, be surrounded by an infiltrated area, and thus obscured may lead to confusion with tuberculosis, but the mottling characteristic of that condition will be absent. The fluid of the abscess will usually contrast further with the air-filled cavities of phthisis. Location of an abscess for subsequent operation will be greatly simplified and assured by an X-ray examination, but this must be carefully undertaken, the chest being first viewed in all positions and stereoscopic views taken with the plates on that aspect of the chest wall nearest to the abscess. The position of the abscess should also be indicated, as explained in the chapter on localisation.

Pneumoconiosis or **Silicosis,** produced by inhalation of irritant dust particles, may on a radiogram *simulate extensive tuberculosis. Fibrous changes* are present in the hilum, along the bronchial ramifications and in the finer bronchioles, and those produce *opaque markings* and a generalised *mottling* very like the "woolliness" of active tuberculosis.

The mottling is *finer* than in ordinary cases of phthisis, but may closely simulate the miliary type. The *apices*, however, are *not* usually involved, the changes are *symmetrical* in the two lungs, and the history and physical signs will differentiate. Tuberculosis may be superimposed upon this condition, and its occurrence will be indicated by a loss of definition of the shadows of individual nodules and the appearance of one or more areas of "*clouding*" of the lung field hitherto uniformly mottled. This clouding may be *unilateral* and in all cases probably *unsymmetrical.*

An interesting paper on this condition, with set of illustrations, appears in the "Archives of Radiology and Electrotherapy" for Feb., 1923, by Dr. Steuart, reporting the experience of the Miners' Phthisis Medical Bureau in Johannesburg.

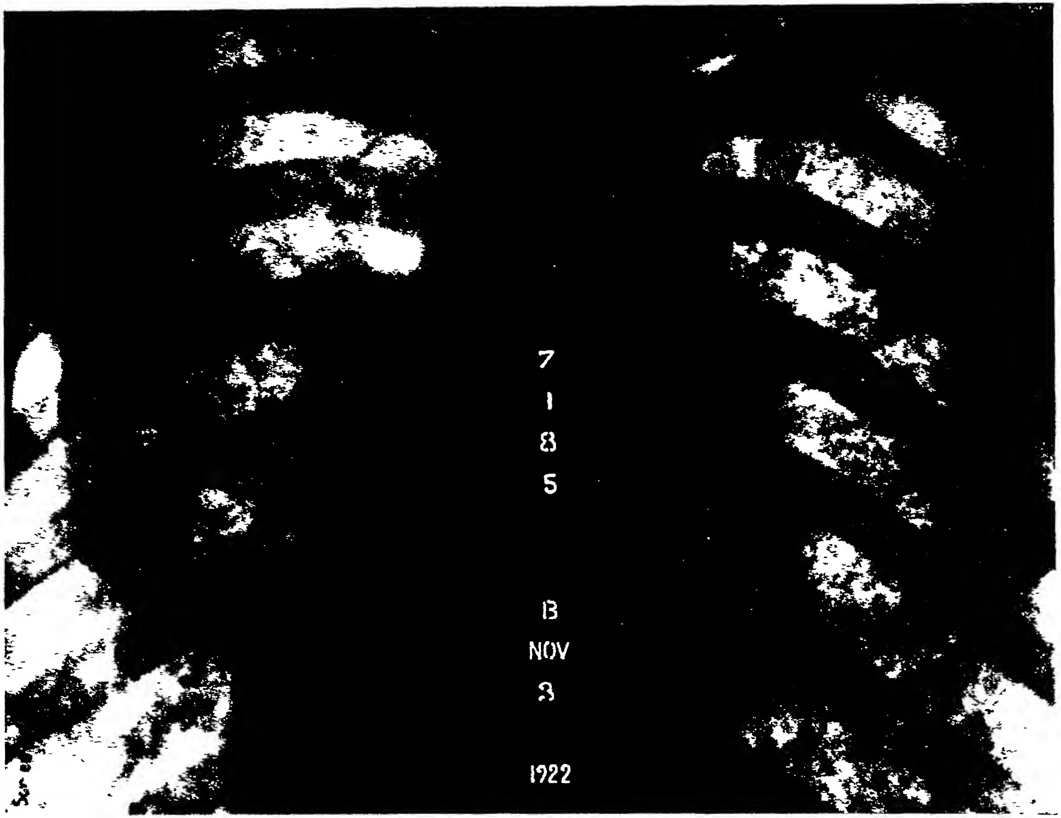


Fig. 355.—SILICOSIS (EARLY).

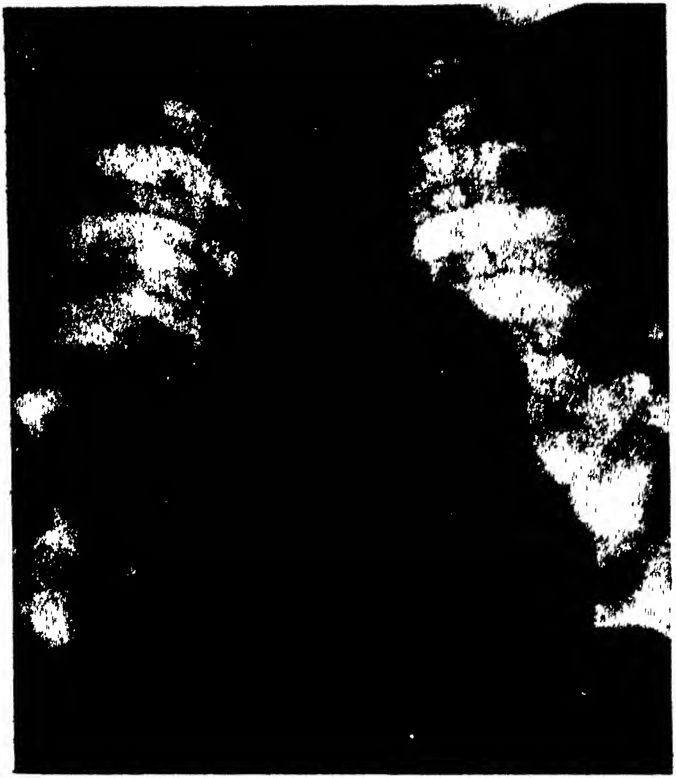


Fig. 357.—SECONDARY GROWTHS IN LUNG.

Plate LIX.

Metastatic Malignant Growth infiltrating the lung tissue, as in Fig. 356, may also *simulate tuberculosis*, but the small centres of opacity are usually more dense and sharply defined, whilst the larger centres are more irregular in size and shape, as in Fig. 357.

The history of a case will invariably suffice to settle the diagnosis.

Neoplasm in the thorax casts a dense shadow, in contrast to the transradiant lung tissue, with density grading from its centre radially outwards. Cavities of ragged irregular outline

Fig. 356.—Metastatic New Growth ("Lymphangitis Carcinomatosa").

may appear in the dense area, and, accompanying the main shadow, there will probably be other appearances, produced by coincident pulmonary conditions such as congestion, pleural effusion, and enlargement of bronchial glands. The latter may simulate thoracic aneurysm, though the nature of the shadow is usually such as to define the difference.

In such cases the thorax must be viewed and radiographed in the right anterior oblique position, which is explained in diagnosis of aneurysm, as described in the following section.

Fig. 358 shews a left lung invaded by such a tumour, which also involved the anterior mediastinum; the tumour in Fig. 358 more directly affects the lung itself.

Syphilis, in the rare cases affecting lung tissue, may produce a general thickening of the bronchial markings radiating from one or both hilar regions, or dense massive shadows due to gummata in that region, or the whole of one side of the chest may be obscured by a diffuse shadow resulting from bronchial stenosis. Fig. 359 illustrates a case of syphilitic fibrosis affecting the upper lobe of the left lung.

Those appearances are not in themselves diagnostic, but the specific cause may be suggested by the very extensive evidence of departure from the normal as compared with the general condition of the patient.

Diaphragmatic Hernia and Eventration are conditions not very commonly met with, but their presence and differentiation may be conclusively determined by radiography. In both of those conditions abdominal organs—usually the stomach and occasionally also part of the colon—are found above the normal boundary line of the diaphragm. This finding accentuates the importance of examining below the level of the diaphragm as well as above it in all thoracic conditions.

In *hernia* there is a rupture of the diaphragm, whereas in the kindred condition known as *Petit's eventratio diaphragmatica* there is no actual rupture, but rather a distension or ballooning of part of the dome. (Both terms are somewhat misleading, since there is no sac to the hernia, nor does the eventration actually go "through or out of" the diaphragm, but the conditions are so termed and recognised.) *Hernia* is congenital or acquired; *eventration* has usually been said to be always congenital or at least due to a congenital weakness of the diaphragm.

Dr Woodburn Morison, in a piece of research work representative of the valuable service that radiology may render in obscure problems of diagnosis, has recently made a study of those two classes of cases, and he adduces convincing evidence of the occurrence of eventration following unilateral interference with the phrenic nerve by such causes as tumour, tuberculosis and aneurysm. He therefore argues that in addition to congenital cases due to defect in development of the muscle of the diaphragm, there are many cases due to unilateral paralysis produced by injury to the phrenic nerve at birth, or by some pathological lesion involving that nerve.

NOTE.—See *Archives of Radiology and Electrotherapy* for May and August, 1923.

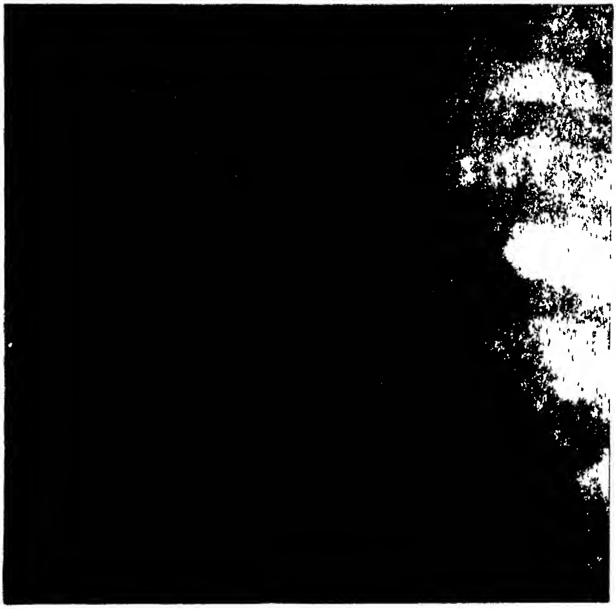


Fig. 358.—NEOPLASM—CARCINOMA.

Fig. 359.—SYPHILIS—FIBROSIS OF LEFT UPPER LOBE

Plate LX.

Fig. 361.—Eventration of Diaphragm.

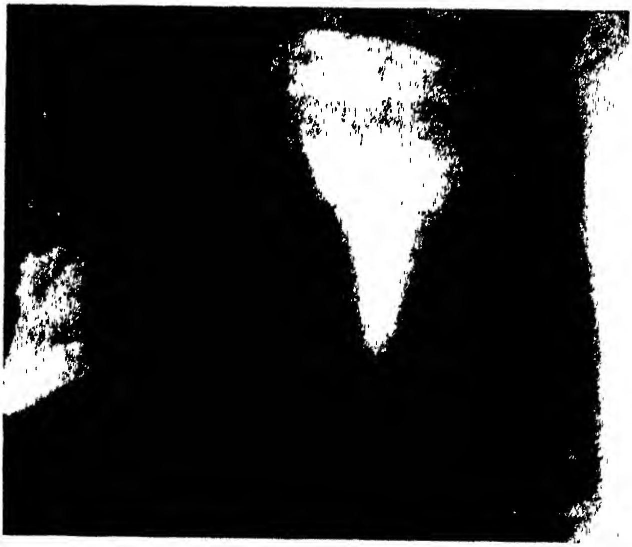


Fig. 362.—Hernia through Diaphragm.

Plate LXI.

Fig. 360 strikingly illustrates the basis of his argument, the radiogram reproduced having been exposed solely for the aneurysm obvious in the figure but found to reveal as well an eventration of the diaphragm, probably due to pressure of the aneurysm on the phrenic nerve.

Many of the signs commonly quoted as differentiating between hernia and eventration radiologically are found to be so variable as to be of little value; such are (*a*) the appearance of lung tissue seen through the shadow of the stomach air-cap, (*b*) presence or absence of the colon in the protrusion, and (*c*) position of the heart.

Fig., 361 from Dr. Morison's large collection of cases, demonstrates the one reliable point of differentiation, namely,

Fig. 360.—ANEURYSM WITH UNSUSPECTED EVENTRATION.

the *unbroken bow line* of the distended diaphragm present in eventration but not in hernia. Fig. 362 shews by contrast the appearance in hernia, the stomach in both figures being occupied by an opaque meal. The *movements* of this bow line may be corroborative. In eventration, unless adhesions interfere, there are noted free *reverse movements* of the protrusion—the so-called "paradoxic respiratory phenomenon." Thus, on forced inspiration, while the normal side of the diaphragm descends, the protrusion on the other side will be seen to rise (forced up by increased abdominal pressure), and when the normal diaphragm rises the protrusion will descend. This may occur in hernia if the protrusion be very small, but if the hernia be extensive, as it usually is, no movement in it will be visible.

An opaque meal, as described later in discussing diagnosis in the abdomen, with the patient in the recumbent posture, will distinctly reveal the abnormal position of the stomach and will help to differentiate between the two conditions.

HEART AND AORTA.

The heart and great vessels are projected in the median shadow seen in all views of the thorax. A description of this median shadow will be found on page 379, and its normal appearance is reproduced in Fig. 332. The accompanying diagram (Fig. 363) recalls its form, and indicates the structures producing it.

The outline is most distinct on deep inspiration, due to the stronger contrast of the expanded lung tissue, but the patient should not be instructed to breathe deeply or to hold his breath, as such interference with normal respiration will affect the size and shape of the heart.

Concerning the heart itself, much may be learned directly

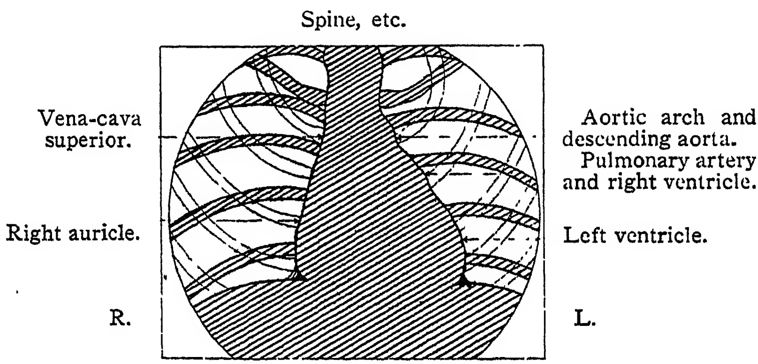


Fig. 363.—SKETCH OF NORMAL CARDIAC SHADOW.

and indirectly by noting changes in position, form, and relative dimensions of the shadow.

Enlargement of the organ may thus be diagnosed, and possibly ascribed to one or other of its compartments, though with some hesitancy. To differentiate in such enlargement between hypertrophy and dilatation by this method of examination alone—as has been done, at least in print—makes a totally unjustifiable claim for its value.

Displacements have been discussed relative to their causative conditions in the preceding sections, and can certainly be more accurately estimated in most cases by X-ray examination than by percussion.

For measurement of dimensions orthodiagraphy should be employed, as described in the following chapter, since the

enlargement and distortion inseparable from a radiogram as ordinarily exposed makes any measurement from such a record very unreliable. To minimise this effect all ordinary radiograms of the heart should be taken with the plate or film apposed to the anterior chest wall, and the tube should be set as far away as may conveniently be arranged.

At a distance of 30 in. from tube to plate the distortion may be disregarded for the purpose of qualitative diagnosis, but no quantitative record should be attempted.

With any method of observation there will always remain a doubt as to how much of an alteration observed may be due to change in size of the heart, and how much to change of position.

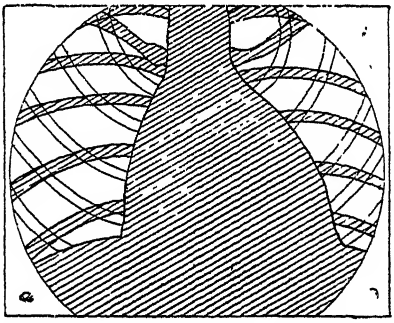
R.  L

Fig. 364.—Sketch of Shadow in Pericarditis.

Despite the uncertainty, however, of absolute measurements certain relative observations are of decided value.

Pericarditis, if accompanied by fluid effusion, will be made evident by marked increase in the area of the cardiac shadow, which assumes a rounded appearance, in contrast to the typical form described. The extent of this will, of course, depend upon the amount of fluid present in the pericardial sac.

The *cardio-phrenic space* may be obliterated, and the pulsation usually seen at the left border will be diminished or abolished. Fig. 364 represents the form of the median shadow in pericarditis with a moderate amount of fluid, sometimes described as the "*water-bottle*" shape. On the patient *lying down* the increase in width appears more towards the apex of the triangle, an observation which may differentiate between this condition and enlargement of the heart itself.

Mitral Stenosis produces a characteristic form of the cardiac shadow, due doubtless to the enlargement of the right side added to that of the left. The form of the shadow, as seen from annexed sketch (Fig. 365), resembles that of a purse, and is so described.

Mediastinal masses alter the form of the median shadow more towards its upper part, as may have been noted in some of the radiograms reproduced in earlier sections on affections of the lungs.

The opacities seen about the median shadow in lung conditions are usually due to *enlarged glands*, which enlargement may be caused by malignancy, lymphadenoma or, most

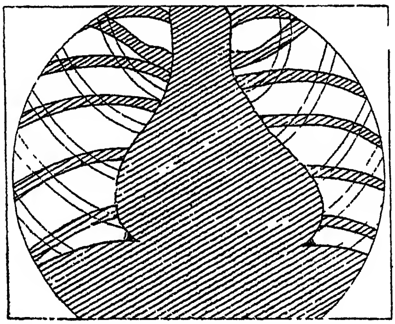


Fig. 365.—Sketch of Shadow in Mitral Stenosis.

commonly, tuberculosis. Such glands shew a sharp and irregular outline, and similar opacities will be noted along the course of the larger bronchi, as seen in Fig. 366.

As contrasted with aneurysm, an increased width of shadow due to enlarged glands is irregular and *bilateral*, whilst it does not usually shew pulsation, although large masses may occasionally transmit the pulsations of the heart or aorta.

A new growth will produce a broadening more definitely *unilateral* with sharply defined outline, and without the radial extensions common in glandular enlargement. This may simulate aneurysm, as pulsation is commonly transmitted by the tumour mass, but differentiation is usually possible if the thorax be viewed in the *right lateral oblique position* referred to in the succeeding section. In this view the tumour mass will be seen to be *separate* from the normal aorta.

Fig. 366.—ENLARGED BRONCHIAL GLANDS.

Fig. 367.—MEDIASTINAL TUMOUR.

Plate LXII

R.  L.

Fig. 368.—Aneurysm of Ascending Arch of Aorta

R.  L.

Fig. 369.—Aneurysm of Transverse Arch of Aorta.

Plate LXIII.

Thoracic aneurysm may be detected in alteration of the median shadow as a *bulging* to one or both sides of its upper part, about the level designated as the *left aortic bulge* (see Fig. 363). The extra shadow is usually bounded by a well defined rounded border, more regular and distinct than those described as due to other mediastinal masses.

This aneurysm shadow may or may not show *pulsation*. X-ray examinations seem to shew that the emphasis put on this latter sign as pathognomonic of aneurysm is exaggerated, for in many undoubted cases no special pulsation is seen.

The *heart* shadow so frequently assumes a more *transverse position*, with displacement downwards, that the appearance has come to be definitely suggestive of aneurysm, and especially in aneurysm of the ascending arch may this be noted. In Fig. 368, which represents an aneurysm of the ascending arch, the alteration in position of the heart may be noted.

When the abnormal shadow is chiefly to the *right* side, and fairly *low* down, we may diagnose aneurysm of the *ascending* aorta (as in Fig. 368); when the shadow is *higher* up, and on *both sides*, we may locate it to the *transverse arch* (as in Fig. 369); and when *lower* down, to the *left* side, we may locate it to the *descending* part of the aortic arch. This indication is mainly relative, but usually distinct enough to satisfy practical requirements.

The shadow seen in the posterior or anterior position of screen or radiogram is a much *exaggerated and distorted* view of the aneurysm, and the degree of distortion will depend on the situation of the swelling in the thorax; hence comparison of size is made very difficult.

For this reason the *orthodiagraph* (as described in the following chapter) is of great value in estimating the true dimensions of the aneurysm as recorded by its shadow, and for noting its progress.

Very useful also is the right anterior oblique position of exposure, first described by Holzknecht about 1901. This serves to differentiate aneurysm from other conditions causing similar forms of shadow.

The right anterior oblique position indicates a method of viewing the thorax whereby the constituents of the median shadow seen in anterior or posterior views are separated up to some extent. By placing the X-ray tube to the left of the spinal column behind, and about the level of the sixth dorsal vertebra, rays may be passed between the lateral fronts of the vertebræ and the descending aorta, so as to shew on a screen placed to the right of the mid-line in front a narrow, clear space bounded by two parallel shadows.

In this position the shadow of the descending aorta will be superimposed on that of the ascending arch, merging lower into that of the heart. Fig. 370 shews diagramatically this arrangement, and explains better than words the result. The usual directions given are to place the tube and screen in a line making angles of 45° with the axis of the body, but this is not correct. As will be seen from the diagram, the position required is more nearly in a line making an angle of 30° with the dorso-ventral axis, and this will be found in practice to be more nearly the correct angle for a clear view.

Unfortunately, a radiogram taken in this position is somewhat indistinct and difficult to reproduce in printed illustration, so that to follow the description of the appearance it will be better to refer to the diagram in the lower part of the sketch opposite. This is shewn as projected on a screen placed in front of the thorax, which is, in the upper part of the diagram, shewn in section through the eighth dorsal vertebra.

To either side are clear areas corresponding to lung, and centrally there is a narrow clear area, bounded on one side by a parallel-sided shadow of the vertebral column, and on the other side by a shadow, roughly triangular in form, produced by the superimposed parts of the aortic arch and, lower down, by the heart. This central clear area corresponds roughly to the posterior mediastinum, so that abnormal masses in that region will be revealed as opacities occupying that space. By rotating the patient whilst under screen observation, such mediastinal masses may be seen to be separated from the aorta, and in a radiogram fortunately oriented the same distinction may be possible.

Thus, in Fig. 371, opacities due to enlarged glands are plainly seen to be independent of the darker aortic shadow in front.

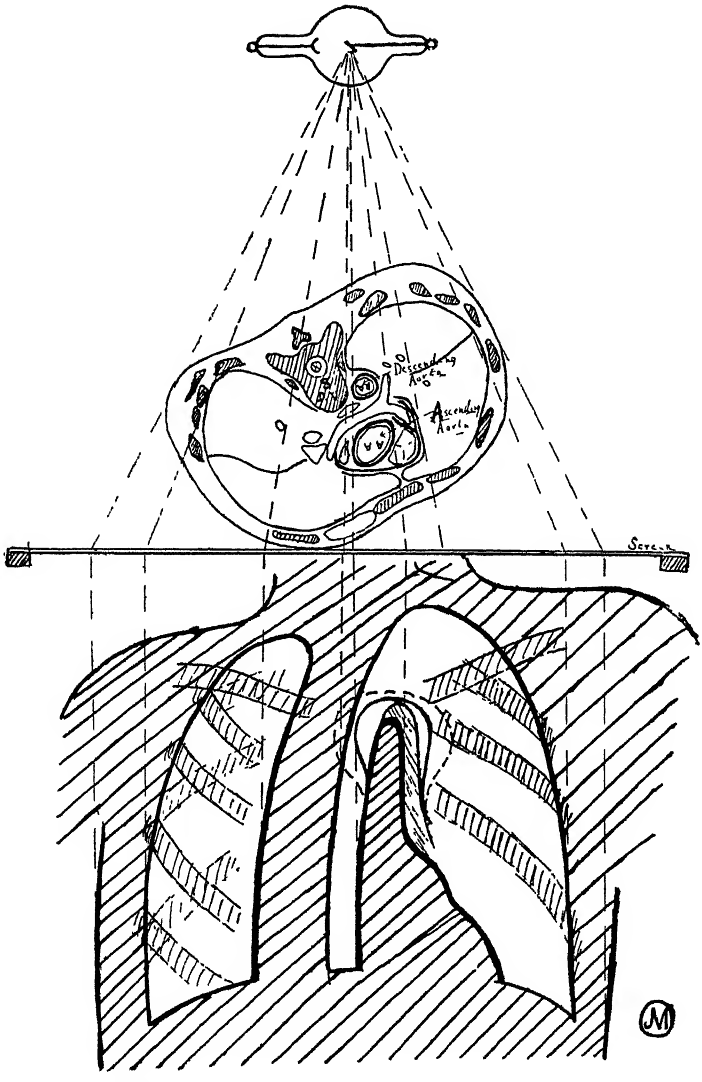


Fig. 370.—SKETCH OF RIGHT ANTERIOR OBLIQUE POSITION AND PROJECTED SHADOW.

Fig. 371.—Radiogram in Right Anterior Oblique Position.

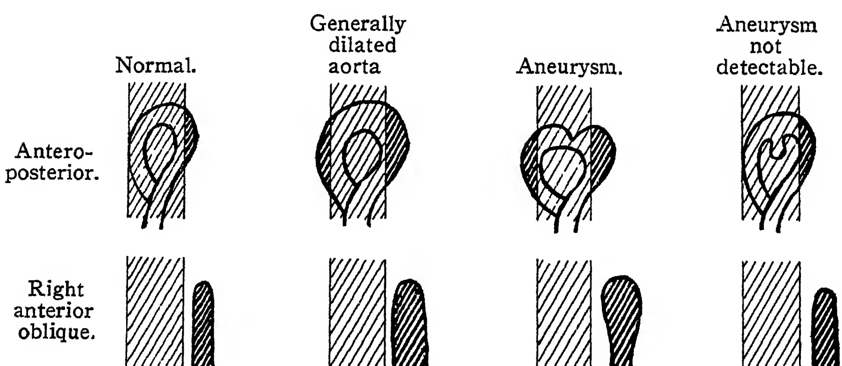


Fig. 372.—Sketch of Aortic Shadows as in Antero-Posterior and Right Anterior Oblique Positions of Screen.

Plate LXV.

The upper end of the triangular shadow is rounded, and normally has parallel sides for some distance from the top till it merges into the cardiac shadow, which ends on that of the diaphragm. The normal form is indicated by the heavy line continuous with the cardiac outline in Fig. 370.

It is to the rounded upper end of this "aortic shadow band" that attention should be paid. Even a very small *aneurysmal swelling* anywhere on the aortic arch produces a notable change in this, causing the end to become *club-shaped*, as shewn by the thinner line surrounding an unshaded area in the figure. The size of the club-head shadow will depend on the size of the aneurysm, a larger size being shewn in broken line, which reaches partly across the clear left lung area, and encroaches also on the vertebral shadow. Only one form of aneurysm can fail to reveal itself in this shadow, and that a rare one—namely, one forming on the bottom side of the transverse arch, and projecting downwards between the ascending and descending arches.

From a *generally dilated aorta* this view will also serve to differentiate an aneurysm, for the former condition will produce a shadow band of greater width, but still *with parallel sides*, as shewn by area of lighter shading in Fig. 370. Such a condition would nevertheless produce a marked broadening in the aortic region of the antero-posterior shadow, and might be very misleading, in which case the value of this additional position may be understood.

Slight irregularities in the "aortic shadow band" may be produced by other conditions than aneurysm, but in no other condition is the marked clubbing due to aneurysm reproduced. If the aneurysm be situated low down on the ascending arch of the aorta, the rounded club-head may be situated lower down on the band and tail off towards the top end.

Fig. 372 reproduces the appearances of antero-posterior shadows of certain conditions, and shows in parallel the shadows of the same conditions viewed in this oblique position. From this figure it will be seen how possible errors from the former view may be avoided by combining with it the latter.

The figure is self-explanatory.

A *left posterior oblique* position of the screen may be adapted from the foregoing one by substituting the tube and screen for each other.

Pneumo-pericardium.—Figs. 373 and 374 reproduce two views of a case reported from University College Hospital by Dr. Salmond. The left-hand view shews a condition of hydro-pericardium which completely obscured the outline of heart and median shadow.

Air was accidentally admitted to the pericardial sac, the fluid became absorbed, and the contrast shadows, as seen in the right-hand view, clearly revealed the source of trouble. This was a cyst in the posterior mediastinum, which was subsequently removed with a brilliant result, towards which

Fig. 373.—Hydro-Pericardium from Unknown Cause.

Fig. 374.—Pneumo-Pericardium revealing Cyst pressing on Upper Part.

the radiological diagnosis contributed an essential factor. The case is reported in full in the "Archives of Radiology and Electrotherapy" for June, 1923, and constitutes a most interesting, although accidental, demonstration of the potentialities of radiology.

Opaque Injection of the Vascular System.—Fig. 375 represents the result of a method employed to render the vascular system subject to study by radiography. This aid to the study of anatomy is an extremely interesting application of radiology, although its bearing upon the diagnosis of disease is somewhat indirect. The figure is from a series published by Mr. H. C. Orrin in the "Archives of Radiology and Electrotherapy" for March, 1919.

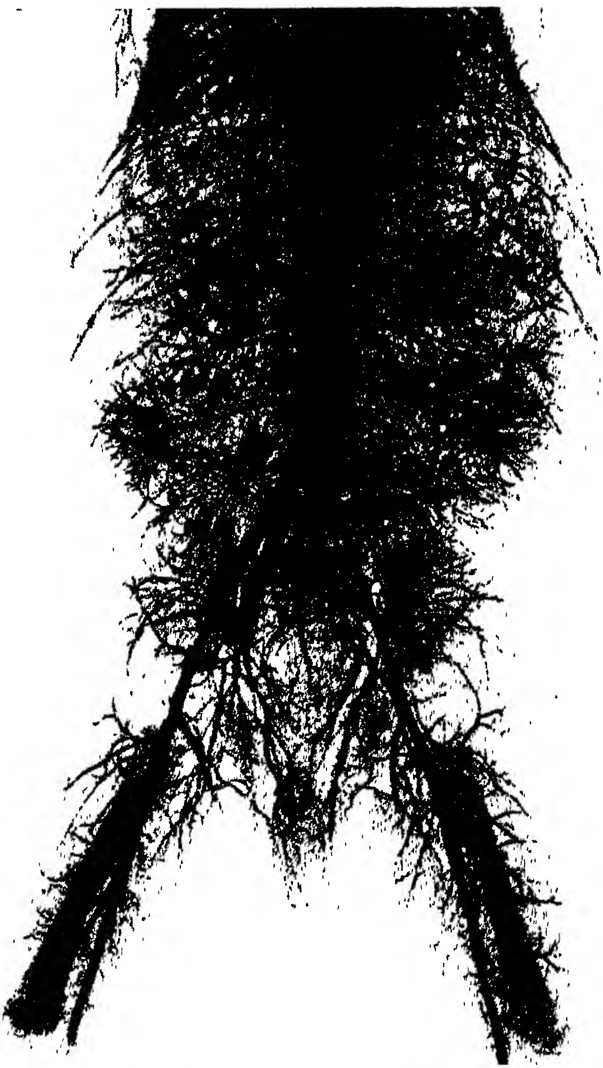


Fig. 375.—Opaque Injection of the Vascular System.

Plate LXVI.

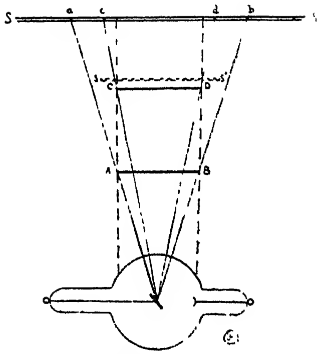


Fig. 376.—SKETCH SHEWING CENTRAL PROJECTION

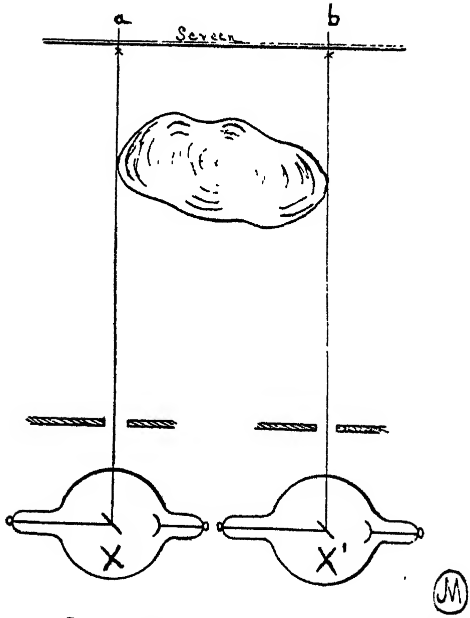


Fig. 377.—SKETCH SHEWING PARALLEL PROJECTION.

Plate LXVII.

magnification may be practically ignored, as in radiograms of the bones of a limb, and as shewn at C D and S′ S′ in Fig. 376. But where the screen or plate can only be placed in position at some considerable distance from the object which intercepts the radiation, then, as shewn at S S, the magnification demands attention, or may lead to difficulty and confusion in interpretation of the radiogram.

Distortion of form and of relative position of objects is also produced by the same fact of divergent radiation where different points of the same object, or of adjoining objects, are not equidistant from the point of origin of the rays. Such is the condition of affairs in radiographing the thorax, and the "median shadow" produced is a magnified and distorted image of the objects producing it. Thus a heart-apex, correctly defined by percussion as lying behind the fifth intercostal space, when viewed by a tube set behind the central point of the thorax, may have its shadow appear as in the eighth or ninth space.

Description of Method.—Orthodiagraphy is a method whereby this misleading element of magnification and distortion is eliminated, and a record obtained of the true dimensions in one plane of objects exposed. The principle is that of using only the central ray, or bundle of parallel rays, which proceeds from the antikathode in a line perpendicular to the desired plane. By movement of the tube this "normal incident ray" is made to follow the outline of the object exposed, so as to cast on the screen a tangential shadow of each point. A tracing of this path of movement of the tube gives the desired record.

This will be understood more readily from a description of the actual process.

Several special arrangements of apparatus have been designed for the purpose of this method (see Fig. 380), but the principle is alike in all, and the variations are solely in mechanical design for convenience of working. The description here alludes to a simple fitting which may be added to an X-ray table used for general purposes. This consists of a side-link, shewn in Fig. 378, by which the fluorescent screen, supported horizontally on the upper frame of the table, may be moved synchronously with the X-ray tube below, and a marker, shewn in Fig. 379, which is attached to the tube box so as to trace the movement of the latter. On the back of the screen are stretched two fine wires, joining the middle points of opposite sides, and crossing at the centre of the screen.

Close above the tube are stretched two similar wires, crossing opposite the central point of the diaphragm, exactly beneath which the focal point—or area—of the tube should be set. With all centred properly, the respective shadows on the screen of the two sets of cross wires will coincide.

With an object interposed between the tube and screen, and the point of crossing of the wires set opposite any point of the outline of the shadow, it will be seen that this point on the

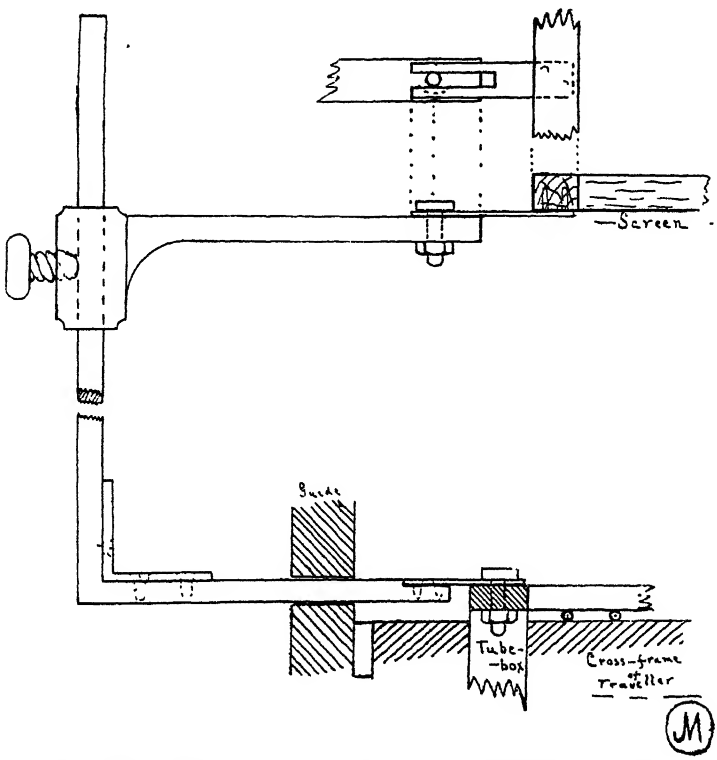


Fig 378.—Side-Link for Table for Orthodiagraphy.

screen is the perpendicular projection on the plane of the screen of the corresponding point of the object.

This is illustrated in Fig. 377, and from that it will readily be seen that the distance *a b* will correctly indicate the dimension of the object from A to B in the horizontal plane.

If a series of points of any object be thus projected, and the points of projection be suitably registered and joined up, a projection of the object relative to the plane of the screen will be obtained, and exact measurement may be made from it. It is better to mark a series of points, and to join those up, than to attempt to trace a consecutive outline in one process.

To register those points, the usual method adopted is to travel the point of incidence of the central ray (as indicated by the crossing of the wires described above, or by some other suitable contrivance) around the shadow outline, and let its path be traced, or points marked, by some means on a paper fixed parallel to the plane of the screen.

The detail of such tracing arrangement varies in different forms of apparatus; that shewn in Fig. 379 is simple and will serve to illustrate the idea, the figure being self-explanatory.

With a patient on the table ready for examination, and the

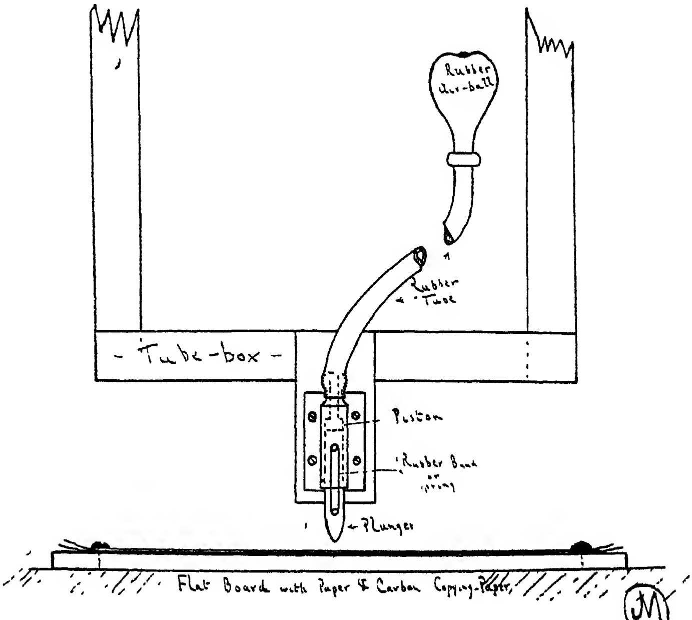


Fig. 379.—Mechanism for Registering Orthodiagraphic Tracing.

tube centred as directed, the crossing of the wires should be set near the centre of the area of which it is desired to trace the outline. The board, with papers fastened on it to receive the record, is placed so that its centre is opposite the marking point, and the current then switched on. The tube and screen are now moved till the shadow of the wire crossing is at a definite point of the shadow outline (in the usual median shadow such a point is one of the angles at the junction of heart and diaphragm), and a mark is made by squeezing the bulb. The crossing is then moved to a point farther along that side of the shadow, set exactly on the edge of the shadow, and another mark made. As in percussion, the wire crossing should be moved from the clearer lung area towards the edge of the

shadow. In this way the marking proceeds round the shadow, the distance between points marked being regulated according to the regularity of the connecting outline, so that by joining up the marks a fairly accurate representation will be obtained of the outline traced. A few ribs should be denoted as land-

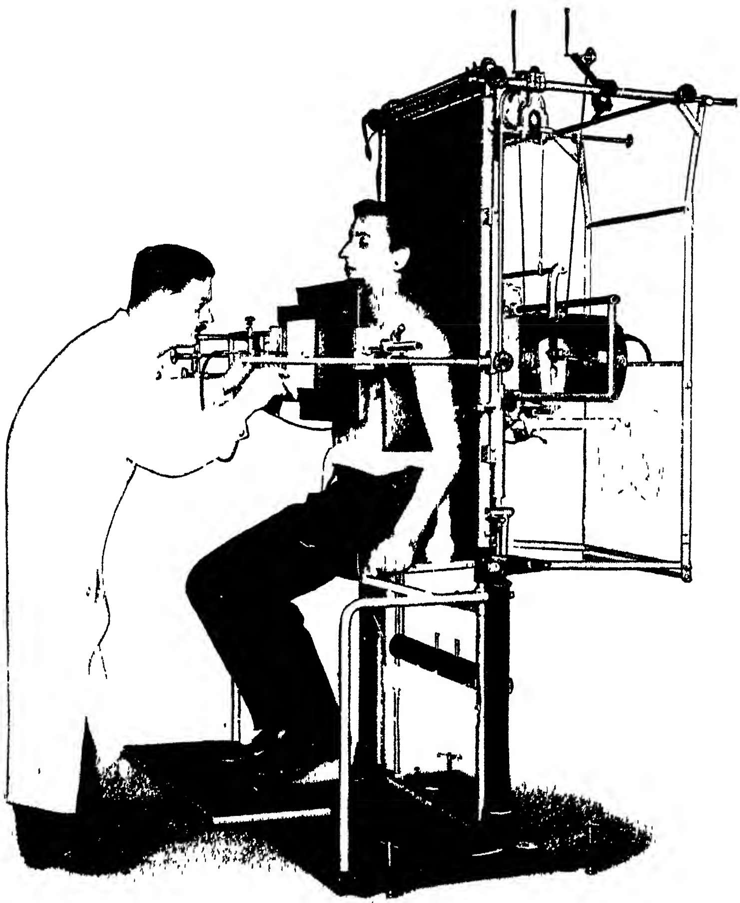


Fig. 380.—Orthoscope in Vertical Position.

marks, along with the centres of the sternal notch and ensiform process, to denote the middle line.

For many purposes it is desirable to secure such a record with the patient in the erect posture, and this can readily be done (as shewn in Fig. 380) by apparatus designed for the purpose. The principle of the process remains the same, and to apply it to the upright position is merely a question of mechanical arrangement, so need not be entered upon here.

Such a piece of apparatus may be more convenient for intermittent use, when made separate and independent from the arrangements for ordinary radiography.

Fig. 380 shews such a design and well illustrates the possible elaboration and precision, but the simple apparatus described serves to illustrate the principle of the method.

Application of Method.—By means of this orthodiagraphic method an exact record may be obtained of the form and movements of the thoracic viscera.

Thus, the *position* of the ribs and of the diaphragm may be registered at completion of inspiration and expiration in various types of breathing. The *excursion* of the two sides of the diaphragm from such record may be accurately compared, and

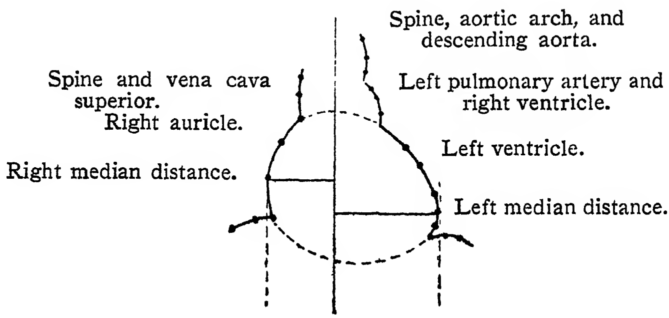


Fig. 381.—SKETCH OF ORTHODIAGRAPHIC SHADOW OF HEART.

inferences may be drawn from that and other data, as described in the preceding chapter (page 383).

The true form of the *median shadow* is also obtained, the normal appearance of which is represented, as so traced, in Fig. 381. The general form, and the structures producing it, correspond to those described for a normal radiogram on page 379; the latter are marked on the figure opposite corresponding parts of the shadow outline.

Through such an outline, when obtained as described in preceding paragraphs, the mid-line of the body should be drawn, and to that perpendiculars should be drawn on either side from the two most distant points of the outline. These perpendiculars are termed respectively the right and left "*median distance,*" and together measure the "*transverse dimension*" of the heart. Other lines are suggested to measure the "longitudinal diameter" of the organ, and to indicate its inclination to the vertical axis of the body, but for practical purposes the two shewn in Fig. 381 are all that are required.

This transverse dimension is in most cases less than the greatest diameter of the heart, since the plane of that does not lie parallel to the transverse axis in which the screen is placed. Absolute dimension, however, is not really the criterion aimed at. So long as records are obtained relative to one plane, and therefore comparable with each other, the method fully satisfies diagnostic requirements. In normal hearts, or hearts with right-sided enlargements, the greatest diameter is always approximately in the same plane. With much dilatation of the left side the heart may be rotated and the plane altered somewhat, but before that occurs the enlargement will be relatively unmistakable, though the tracing may record it as absolutely less than it actually is.

Hence the records obtained in all cases may be relied upon to indicate *comparable dimensions* if care be taken to make all records under *precisely similar conditions.*

As to the position of the patient during examination—*erect or recumbent*—there is some discussion. In the erect posture the heart lengthens and narrows perceptibly, there being probably also an actual decrease in volume as compared with the recumbent posture. Thus, records in either position must not be compared or confounded with records in the other, and note should be made on each record of the position of the patient during its production.

Between the two positions there is no very strong reason for preference, but, whatever position the patient may be in, it is essential for precise comparison to see that he is set so that the central ray will pass in a direction *perpendicular* to the transverse diameter of the chest. Slight divergence from this may produce a considerable difference in the projected shadow.

Respiration affects the form of the cardiac outline somewhat, inspiration causing a slight narrowing, similar to the effect of the erect posture. The clearer lung area in that phase renders the outline more defined and more easily marked; hence the record may be made while the patient holds successive deep inspirations. Otherwise the middle phase of respiration is usually chosen as a safe average.

As to the heart itself, so little change is produced in the

outline by the pulsations that there seems no necessity to insist on a special period for marking each point. That would, indeed, in many cases be quite impracticable, and always difficult. Because of the longer duration of diastole, probably most records are made in that phase, and this should be aimed at if any cognisance be taken of the point.

Of actual dimensions published tables shew considerable range of variation in the normal. One set of measurements gives the following figures, which may be taken as representative :—

			Right median distance	Left median distance
For male weighing	120 lbs.		3·7 cm.	7·2 cm.
„	„	200 „	4·2 „	8·7 „
For female	„	100 „	3·3 „	6·8 „
„	„	175 „	3·8 „	7·9 „

The orthodiascopic outline will shew characteristic changes due to aneurysm or other pathological condition of its constituents. These changes will correspond more or less closely to those already described in radiograms of the various conditions, and need not be recapitulated here, as this method does not aid in their differentiation, though giving a more exact record of the form of their shadows.

As a means of noting the progress of an enlargement of the shadow orthodiagraphic projection is of special service, and with experience of its use and records it is of great value as a method of precision.

It seems possible that the method might be applied to determine pelvic measurements, but no reliable results seem yet to have been obtained in this field.

Objection to the method has been raised on the ground of the exposure of the operator to a dangerous amount of radiation, but this difficulty is not insuperable. Thus, one source of possible over-exposure of the hands may be avoided by the use of foot-gear for operating the marking mechanism, and other precautions will naturally be observed by an intelligent operator.

CHAPTER XII

DIAGNOSIS—ALIMENTARY SYSTEM

Gastro-intestinal Tract; Liver and Gall Bladder

In recent years much valuable work has been done in X-ray examination of the abdominal organs. On account of the complete transradiancy of the air-filled stomach and intestines, little or no information can be gained regarding those organs by direct unaided transradiation; thus, for many years abdominal diagnosis was restricted to assistance in problems regarding the presence of calculi in the kidneys or urinary bladder, later extended to the gall bladder.

After the ingestion, however, of a suspension of a salt of bismuth—or other *salt opaque to X rays*—more or less accurate outlines of the digestive tract may be traced, and much valuable information may thus be gained regarding the position and movements of the various organs and parts. Much has yet to be learned regarding the normal dimensions and position of the organs concerned, and apparent abnormalities are correspondingly difficult to interpret. Movements are made evident and gauged by the progress of a test meal carrying in suspension the opaque salt mentioned. This relatively opaque mass casts a distinct shadow and is thus traceable on a plate or film as a lighter area or patches. On a screen or in prints it is represented as a darker shadow, according to the usual acceptance of the term, and as already explained in relation to the appearances to be expected on the various records.

By periodical screen examination it is possible to trace the progress of the meal which reveals the position and movements of successive portions of the digestive tract, and films may be exposed to secure a permanent record of interesting phases, or at definite intervals of time.

Bismuth deposited on the walls of the organs may continue for a time to define their position after the bolus has passed, and a radiogram may be obtained shewing the whole, or a large portion, of the tract, but this information is not of much value, the chief assistance in diagnosis being obtained by noting the

nature of the functional movements of the parts and their shape and size when fully occupied by the opaque meal.

Observation on the fluorescent screen is essential for functional observations, whilst *plates or films* serve to record organic conditions as well as to provide a permanent record to accompany case reports or to file for future reference.

Valuable help may thus be rendered in diagnosis, but the value of the observations depends largely upon close co-operation between radiologist and physician, the latter correlating the appearances shewn or reported to him with the clinical data elicited by other means. A guide to diagnosis of abdominal conditions is not here attempted, but in the following notes, descriptive of the method of operation, points are indicated in regard to which radiology may give valuable assistance.

I. METHOD AND TECHNIQUE OF OPAQUE MEAL EXAMINATION.

(1) **The Opaque Meal.**—Meals of differing consistency have been employed by various observers, some preferring for routine examination a partially fluid meal, such as a suspension of 9 grms. of bismuth carbonate in 500 c.c. of butter-milk and water; whilst others prefer a more solid meal, such as 4 oz. of barium sulphate in ½ to ¾ pint of bread and milk.

Each form of meal has its advantages, and for a critical examination both may be employed. For certain purposes, such as outlining the stomach wall under palpation, a comparatively small fluid mass is preferable, whilst for observing the movements of organs and induction of peristalsis a fuller and more solid meal serves better.

This possible difference in consistency must always be remembered in comparing results, especially if the factor of time enters into the assessment of observed data. A "*standard meal*" for the purpose was suggested by the Royal Society of Medicine, consisting of about half-a-pint of porridge or bread and milk having mixed in it 4 oz. of barium sulphate, to be given in the morning on an empty stomach.

The report (*Proc. Roy. Soc. Med., Electro. Sect.*, 1915, 67) also advised that no aperient should be given within thirty-six hours of the examination. Experiments on this point seem to shew that it is not of vital importance, but most workers order a preliminary aperient in each case, and, where time permits, stipulate that it be given thirty-six or forty-eight hours before

examination, so that its action is complete before observations are commenced.

A meal similar to that quoted is very commonly used, but no standard has been universally adopted in this country, and in other countries still wider variety exists. For comparison of results such a standard would doubtless be valuable, but practice has not yet been sufficiently stabilised to permit of any degree of dogmatism in prescribing detail. Each worker must, however, use some standard meal for his own work, at least for comparable groups of cases; otherwise his results will be chaotic. The "standard meal" mentioned may form a good basis for early work, until experience may suggest some modification for special purposes or for experiment. The vehicle should be such that it holds the opaque salt in suspension, and emulsions in tragacanth are employed as well as substances more directly resembling an ordinary "meal."

Various efforts are made also to render the meal less unpalatable. Thus, Dr. Scott of the London Hospital advises an emulsion made up, under the name of "Ramul," in different consistencies for different purposes.

This is quoted as:—

	No 1. Thick, flavoured for œsophageal cases.	No 2. Medium, flavoured for gastric cases.	No 3 Thin, unflavoured for opaque enemata.
Barium sulphate	10 oz.	10 oz.	10 oz.
Saccharin	2 grs	2 grs.	—
Vanilin	5 grs.	5 grs.	—
Gum tragacanth	100 grs.	60 grs.	60 grs.
Distilled water	ad 20 oz.	ad 20 oz.	20 oz.

Another preparation is made up, under the name of "Umbrose," consisting of an Allenbury food mixed with barium sulphate and flavoured with chocolate. Suitable meals can readily be prepared by addition of barium sulphate to a milk meal prepared in the ward in the usual course, but for routine work in a busy department some special preparation is more convenient, as supplied by the dispensary or made up in the department.

For a time there was some difference of opinion as to the most suitable salt to be employed. *Bismuth* salts were said to

cast a deeper shadow, and to inhibit somewhat the natural movements of the stomach. The subnitrate must on no account be used, as nitrites may be liberated from the large quantity employed, and deaths have been reported from the effects. The carbonate may be used, or the oxychloride. *Barium sulphate* is cheaper, but was said to cast a less dense shadow and to stimulate the movements of the stomach. The effect of the salts of either metal upon the normal movements of the stomach are probably negligible, and there seems little to choose between the two metals for efficiency. The lower cost of barium sulphate will decide the choice for many workers, and that salt is now almost universally employed.

It is pointed out by some observers that the effects of any such meal upon the normal functions of the stomach cannot be considered as physiological, and that the standard set up of a "normal X-ray stomach" is therefore a conventional one, but as a standard of comparison its value is not affected by such considerations so long as the conditions of observation are kept as constant as possible.

(2) **Routine Procedure.**—For complete observation of a case the opaque meal should be traced through its entire course from the mouth to the anal orifice. This is, for various reasons, obviously impossible, but by judicious selection of periods all the salient points may be noted from the behaviour of one opaque meal, and regions shewing pathological or questionable appearances may be further studied as necessary.

Two methods are commonly employed for convenience; one (*a*) employing a *single meal* administered under observation and periodically observed, and the other (*b*) employing a *double meal*, of which the first portion is administered six hours before the patient appears for examination.

(*a*) For the *single meal* any of those already mentioned may serve, but a convenient modification is to administer it in two portions.

The first portion, about 4 oz. and semi-fluid, is swallowed under screen observation, and its course through the œsophagus into the stomach noted.

By manual palpation, or other means, this fluid mass is manipulated so as to outline all parts of the stomach in succession, from the cardia downwards, and irregularities or defects in that outline are noted for further reference.

Its passage through the pylorus and its filling of the duodenal cap beyond is further noted. This done, the patient is now given the second portion of his opaque meal, which may be a further quantity (about half-a-pint) of semi-fluid or a more solid meal, as already described.

The stomach is again observed and manipulated immediately after completion of this meal, and a film is exposed which will register the position and shape of the filled stomach along with the pylorus and duodenal cap. The patient is again observed and films exposed at varying intervals according to the purpose and scope of the examination.

(*b*) For the *double meal* a first full opaque meal ($\frac{1}{2}$ to $\frac{3}{4}$ pint) is taken by the patient in the early morning—say about 7 a.m.—six hours before he is to attend at the X-ray department for examination. At the end of the six-hour period, under normal conditions, the whole of the opaque meal, or all but a very small residue, should have left the stomach, and the position of the forward and rear end of the opaque bolus in the intestine should be noted.

If more than one quarter of the opaque contents remains in the stomach at the time of examination motility is reckoned as abnormal, and the cause of delay should be sought for. The forward end of the column should at that time be at or near the cæcum. After all the points regarding the first, or "motor," meal have been noted, the patient is given a further portion of opaque meal—preferably semi-fluid—by observation of which the condition of the œsophagus and of the stomach and pylorus may be directly observed.

Occasionally the presence of the first portion may confuse the interpretation of the second, in which case the patient may have to be referred for a later examination of the upper regions of the digestive tract. Despite this occasional inconvenience, the general saving in the time of the observer and patient makes this the method of choice for many radiologists, especially for hospital practice.

(3) **Preliminary Inspection.**—Before the meal is taken the patient should be examined in the vertical position by screen, as explained on page 130.

The chest should be rapidly, but thoroughly, inspected, the region of the diaphragm receiving special attention, as abnormalities there may seriously affect abdominal conditions.

The size and position of the liver and spleen should be noted, also any abnormal shadow that may be observed, especially in

the region of the gall bladder, and a plate should be exposed as a record if any abnormality is present.

Figs. 382 and 383 illustrate the possible confusion that may result from failure to make this preliminary inspection.

In one case a calcified hydatid cyst, unrecognised before administration of the bismuth meal, was at first sight mistaken for an abnormal distribution of bismuth shadow in the jejunum; in the second case a cyst in the kidney explained the unusual appearance of the upper pole of the stomach shadow.

The main examination is usually made in the vertical position, but comparison should be made with the horizontal view (as in cases of apparent gastroptosis mentioned later), and some workers lay stress on the importance of examination in

Fig. 382.—Calcified Hydatid Cyst.

Fig. 383.—Cyst in Kidney.

the latter position. Care must be taken, however, to avoid confusion from the distortion effects of pressure against the spinal column, with the patient on his back, and if films be exposed with the patient horizontal, he should preferably be turned face downwards and the tube set above him.

To obviate pressure on a protruding abdomen in this prone position, cushions may be placed under the thorax and pelvis, so as to minimise the pressure of the abdomen on the underlying cassette.

(4) **Landmarks.**—A coin or other piece of metal may be fastened over the umbilicus as a landmark. If, on account of pendulosity of the abdomen, the umbilicus is seen to "drop" markedly in the vertical position, the opaque indicator may be applied over the umbilicus in the horizontal position, and fastened by a strip of material to the skin over the sternum so

as to remain suspended in the same position when the patient stands up. Many surgeons and physicians still demand this indicating mark, but its variability must be remembered and may be very misleading. On this account the horizontal line joining the iliac crests will be found more convenient as a mark of this level, whilst the vertebræ and costal margins serve for further references, as noted later (see Fig. 391).

(5) **Method of Observation.**—As the meal is swallowed, its progress may be watched on the screen and serial notes and sketches made. Plates or films may be exposed to give an accurate and permanent record at set intervals of time, or to record special findings, but serial plates or even cinematograph films may fail to give valuable information obtainable by careful and frequent observations on the fluorescent screen.

Diagnosis from *film or plate* necessarily relies solely upon definite demonstration of *organic* lesions; whereas *screen* observation, whilst demonstrating those same lesions, further permits the interpretation of *functional* changes.

Opinions regarding the relative value of the two methods of examination vary considerably, and zealous advocates have claimed preference for each method almost to the exclusion of the other. In a complete diagnosis, however, screen and plate observations are essentially complementary, and the judical verdict is undoubtedly one of compromise.

By observation on the fluorescent screen the course of the opaque meal may be watched and movements of the stomach wall, as indicated by its change of shape, may be noted. Variations from the normal in shape and outline may also be observed and, though the detail of such may be more critically studied on a film, the question of the permanency of such departures from normal may require to be settled by continuous, or frequently repeated, observation. To obviate the risk of mistaking a passing phase recorded on a film for a permanent condition, certain advocates of the radiographic method—particularly in America—advise the exposure of a large number of *serial films*, by comparison of which the temporary or permanent nature of any noted alteration in shape or outline may be judged.

(*a*) *Disadvantages* pertaining to the *screening* method are (1) the *time* required to be spent over each individual patient by the trained observer; (2) the *prolonged exposure* to radiations which, however filtered, may produce cumulative damage to

the observer (and a more remote possibility of damage to the patient). [See note (a^1) following next paragraph];

(3) The *absence of permanent record* of the data upon which opinions may be based.

(*b*) *Disadvantages* of reliance upon *film* records are (1) possibility of *undue importance* being placed upon an appearance so recorded permanently which may properly be but a *temporary phase*, recurrent or otherwise; (2) the *expense* of the numerous exposures necessary to minimise the probability of the above error.

(a^1) For personal protection of the radiologist screen observation must be minimised in every method of diagnosis, and in prolonged observation of any patient the closer proximity of the latter to the source of radiation must be borne in mind.

The patient should wear a loose-fitting light garment, so that his skin is never directly exposed to the X rays, and a filter plate of 1 mm. of aluminium should always be interposed across the opening of the tube box.

The various points discussed relative to protection in an earlier section (page 155) should all be carefully attended to.

Despite its drawbacks, at the present stage of knowledge screen observation cannot be dispensed with, and for purposes of education and research it has special advantages which ensures its survival alongside any possible future development.

(b^1) If, however, a film method may be devised of sufficient accuracy and economy, that will probably become the method for routine work. Towards economy a simple arrangement has been devised whereby six views of any selected area, such as the pylorus and duodenal cap, may be secured on one plate. Thus, on a 12 in. by 10 in. plate may be secured six views, each measuring 4 in. by 5 in. Fig. 384 shews the method of this procedure. A frame, with a front opening of 20 in. by 15 in., has an opaque back with a central opening measuring 4 in. by 5 in. This frame has a flange around its inner edge to receive the cassette of a 12 in. by 10 in. plate, and when that cassette is set with an angle fitting close into the corresponding angle of the frame, the diagonally opposite sector of the plate will be over the 4 in. by 5 in. opening.

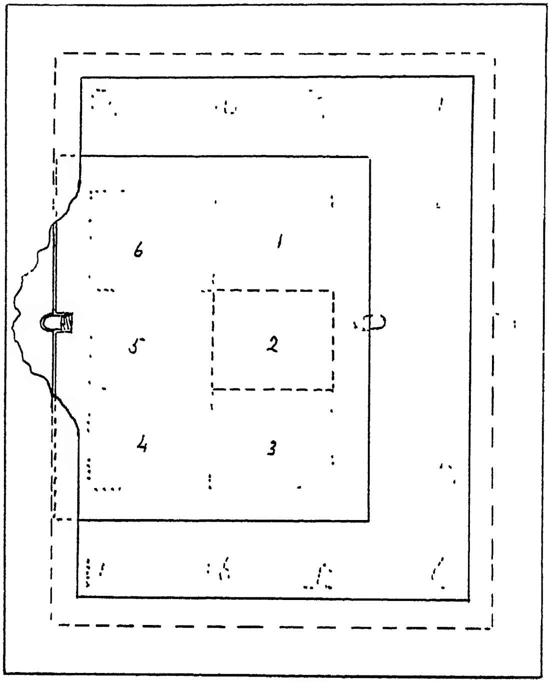


Fig. 384.—Cassette-holding Frame for Serial Films.

Four positions, numbered 1, 3, 4, and 6 in figure, are thus determined; the two intermediate positions, 2 and 5, are determined by a small spring button on either side of the cassette which fits into a corresponding depression on the inner face of the side bar of the frame. By commencing with the cassette in the lower left hand corner of the frame and moving it successively upwards, across to right hand and downwards, a consecutive series, as numbered in the figure, may be secured at three to four seconds interval, or as may be desired.

Fig. 385.—SERIAL VIEWS OF DUODENAL CAP.

Above figure (385) reproduces a film exposed serially by means of the arrangement illustrated in Fig. 384 and described in the adjoining text; various phases of the passage of opaque contents through the pylorus and first part of the duodenum are thus noted.

Another film similarly exposed may be seen, as reproduced in Fig. 418.

II.- THE ŒSOPHAGUS

(1) *Special Technique.*—The progress of the first part of an opaque meal should be observed as it proceeds through the œsophagus, and for this observation the patient should be placed in the *right anterior oblique* position, in which position the shadow of the œsophagus is separated from that of the cervical vertebræ. This position is attained by turning the patient with his left scapula nearer the tube and his right breast pressed against the screen, and he should be rotated carefully until the mediastinal space is seen to be widest.

Fig. 387 shews the view thus obtained, whilst Fig. 371, on page 423, and the adjoining text describes the position in more detail.

To observe the œsophagus, it is convenient to make up 2 to 4 oz. of a thick fluid emulsion (such as No. 1, noted on page 439), and to get the patient to swallow this under observation before proceeding with the main portion of the meal. Normally, this will pass down the œsophagus very rapidly and nothing of special note will be observed.

If there is any apparent delay or doubtful appearance, the patient should next be given a large tablespoonful of very thick emulsion to swallow whilst under observation, and a film exposed to register any abnormal appearance. In place of the emulsion a dry preparation may be given, to be masticated and swallowed, such as the opaque impregnated biscuits known as biscopaks, which serve well for this purpose although unsuitable for a full opaque meal.

An occasional slight delay and retention at the level of the larynx should be noted as of no pathological significance, as also a momentary pause opposite the arch of the aorta, and a more definite initial hold up at the lower end, as if by a physiological sphincter at the entrance to the stomach. Slight pressure at the site of crossing of the left bronchus may also produce a momentary hitch in the progress of the bolus.

Opaque *bougies* and *capsules* were at one time used in investigation of the œsophagus, but those do not furnish so much information as the semi-fluid meal, and are not to be recommended. Bougies are not without danger in the presence of carcinoma or other pathological conditions of the tissues.

Capsules are readily arrested in a normal œsophagus and a false inference may be drawn.

(2) **Obstruction** will be indicated by delay in passage of the meal, usually accompanied by a marked constriction in the shadow at a fixed level, with dilatation above that level, and possibly sacculation. The cause of the obstruction may be pressure from without, as by *aneurysm* or *mediastinal tumour*, in which cases the filling defect is noted usually in the mid portion of the œsophagus; or it may be due to constricting lesions in the œsophagus itself, such as *diverticulum, benign stricture*, or *carcinoma*.

The occurrence of *cardiospasm* or presence of a *foreign body* may simulate the appearances of such causes of obstruction, and must always be eliminated before diagnosis be made of an organic lesion.

The *degree of delay* naturally depends upon the consistency of the test meal employed; hence it is wise, as noted above, in every suspicious case to follow with a bolus more difficult to swallow. In order to evoke spasm, where that may be suspected but is not revealed by the usual emulsion, it is suggested to give dry crumbs or crusts to swallow before the opaque meal is taken. The dry opaque biscuits noted above should serve the double purpose.

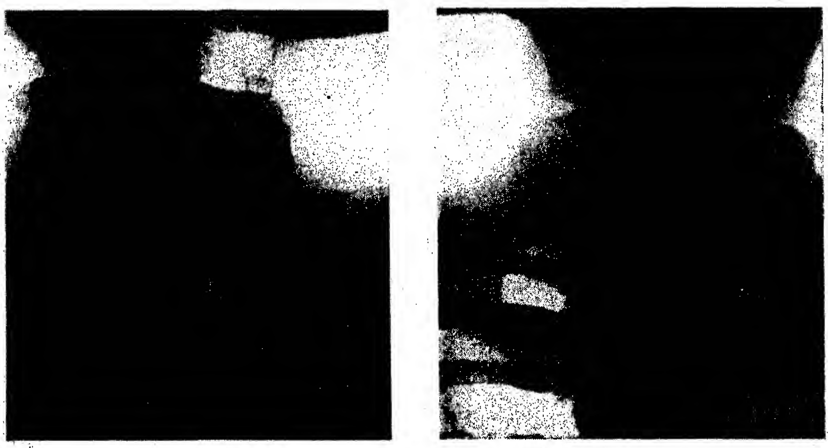
Obstruction produced by *pressure from without* is usually less marked than that due to intrinsic lesions, and may be accompanied by *displacement* of the œsophagus, which will serve to indicate the probable cause.

The conditions producing such external pressure will usually be evident on careful inspection, or on a film exposed in the oblique position.

Dilatation usually follows obstruction from any cause, but is most marked in cases of cardiospasm (see Fig. 390), and is usually less marked above a constriction due to carcinoma than above a benign stricture. The presence of mucous secretion in such a region may delay the filling of the distended lumen, the extent of which may only be demonstrable after lavage of the œsophagus by tube.

(3) A **diverticulum** may be revealed by characteristic alteration in the outline, and by retention of a portion of the opaque meal in its sac. Diverticula are most commonly met with at the upper end of the œsophagus, as in Fig. 386, and, less frequently, at its lower end.

When filled with the opaque meal and seen in profile, the protrusion of the sac to one side of the vertical œsophageal shadow is unmistakable, and when the pouch fills early further quantities of the opaque fluid may be seen to spill over from the horizontal upper limit of the sac shadow into the œsophagus. As such protrusion may be either posterior or lateral, the patient should be rotated until the clearest possible view is obtained. Seen otherwise, a filled diverticulum may be identified by its symmetry and by the smooth roundness of its lower pole.



Lateral View. Postero-anterior View.

Fig. 386.—Diverticulum of Œsophagus.

This appearance may be resembled by a localised *dilatation* of the œsophagus, but the opaque fluid will there be seen to issue from the lowest part of the pouch-like shadow as contrasted with the higher opening of a diverticulum.

The smoothness of outline of the sac shadow may be interfered with by the earlier presence of *solid food contents*, so that in case of doubt the œsophagus and sac should be carefully washed out.

The shadows in Fig. 386 shew some irregularity due to such retained food.

In the absence of opaque substance retained in the œsophagus itself, doubt may exist as to the relations of the shadow, in which case an opaque bougie passed carefully down the œsophagus will clear up the diagnosis.

(4) **Organic Stenosis** of the œsophagus may be due to *cicatricial contraction* following ulceration or traumatic injury, or to the presence of *carcinoma;* and it is at times difficult or impossible to differentiate by X-ray appearances between a benign and malignant source of the abnormality.

(*a*) **A Benign Constriction** may occur at any level, and the shadow of opaque contents retained above its site usually has sharply defined margins with a rounded termination. Some

Fig. 387.—Benign Constriction of Œsophagus.

Fig. 388.—Carcinoma of Œsophagus.

degree of obstruction always occurs, and a varying degree of dilatation is produced, less than that commonly met with in cardiospasm but more than in malignant cases. See Fig. 387.

(*b*) **Carcinoma** occurs most commonly in the lower half of the œsophagus, and the shadow of opaque contents passing through its site may reveal a tortuous and irregular lumen of reduced diameter, as in Fig. 388.

Obstruction and delay may or may not occur in passage of the opaque meal, but dilatation, even in obstructive cases, is less marked than in a similar degree of obstruction from a benign cause. The irregularity of contour as revealed by filling defects is the main differentiating feature.

(5) **Cardiospasm or Achalasia** occurs at the lower end of the œsophagus, affecting usually that small part of its length between penetration of the diaphragm, about the level of the tenth thoracic vertebra, and junction with the stomach, about the level of the disc between the eleventh and twelfth vertebra.

The spasm causes obstinate obstruction followed by dilatation of the higher parts of the œsophagus, which dilatation may reach extreme degrees. Filled out with opaque contents, the dilated œsophagus is seen to end symmetrically in a *smooth*

Fig. 389.—MALIGNANT OBSTRUCTION OF ŒSOPHAGUS.

Fig 390 —CARDIOSPASM (ACHALASIA).

blunt-pointed cone, as seen in Fig. 390, which shape is *characteristic* of cardiospasm.

In obstruction from *benign constriction* or *carcinoma*, the lower pole of the shadow of the retained opaque mass usually shews irregularities contrasting with the smooth conical outline in cardiospasm, but exceptions occur in all three conditions. As in diverticulum, retained food particles may produce a misleading appearance of irregularity at the lower pole of the shadow, and lavage is indicated to avoid confusion.

A glass of hot water may at times relieve the spasm and allow the retained mass to move on into the stomach, thus revealing the nature of the obstruction.

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Fig. 387.—BENIGN CONSTRICTION OF ŒSOPHAGUS.

Fig. 388.—CARCINOMA OF ŒSOPHAGUS.

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Fig. 389—MALIGNANT OBSTRUCTION OF ŒSOPHAGUS.

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A glass of hot water may at times relieve the spasm and allow the retained mass to move on into the stomach, thus revealing the nature of the obstruction.

Spasm may occur at other parts of the œsophagus, with more or less obstruction, but frequently such spasms are transient in nature and their detection fortuitous. Occurrence of spasm may indicate early carcinoma or an abrasion or ulcer of the œsophagus, or it may be reflexly produced by irritation of a gastric lesion.

(6) **Foreign Bodies** in the œsophagus lodge commonly near its upper end or at the crossing, and slight indentation, of the aortic arch. The ease and certainty of the demonstration of such bodies naturally depends upon their composition and corresponding opacity to X rays. Detection and localisation of transradiant bodies may be assisted by noting the arrest or deviation of an opaque mixture swallowed under screen observation.

As already mentioned, it may in some cases be difficult to differentiate between the various œsophageal conditions listed in the foregoing notes.

(7) A summary of the distinctive appearances, as in the following table, may be of assistance:—

Sign in	**Diverticulum.**	**Benign Stricture.**	**Carcinoma.**	**Cardiospasm.**
Obstruction.	By secondary pressure with sac filled.	Variable.	Variable.	Complete, but may yield.
Dilatation.	Improbable.	Distinct.	Slight.	Extreme.
Retention shadow.	Pouch-like, with rounded lower pole and horizontal upper limit.	Lower end rounded, but may be irregular.	Irregular contour.	Smooth, blunt-pointed cone.
Escape of contents.	At top end (spilling over).	At lower pole, regular, symmetrical.	At lower pole, irregular and unsymmetrical.	None, or at point of cone on relaxation.

III. THE STOMACH.

As the opaque meal passes through the œsophagus *the stomach* may be seen to alter in shape as the meal reaches it, dilates it, and more or less completely occupies its lumen. Its shape, position, and movements must be carefully noted, and it should be observed at intervals till the whole of the meal is observed to have passed on through the pylorus. With bismuth the stomach should normally be empty in from two to four hours, with barium in a shorter time.

This difference in rate of emptying should be remembered in estimating the motility of the organ, as discussed later, but it is not of serious import, as any standards fixed for comparison must have wide limits in our present state of knowledge. The data observed must, strictly speaking, be considered merely of relative import and are not to be directly translated as physiological data, since the opaque meal is by no means a normal physiological stimulus.

(1) **The Normal Stomach.**—A "*normal X-ray stomach*" may, however, be visualised or, more correctly, a *normal average*, since appearances may vary considerably within apparently physiological limits.

Its *shape*, *position* and *movements* still require much close observation, as revealed in the living subject by radioscopy, and many notions formed from study of the organ in the operating theatre or dissecting-room must be modified.

Many seeming abnormalities, though striking in appearance, prove to be within functional limits, and only after intimate study of the normal variations and repeated observations of the apparent abnormalities dare an observer be even mildly dogmatic in his conclusions.

Points to be noted may be classified under the headings:—

(*a*) Position.
(*b*) Shape and size.
(*c*) Tone.
(*d*) Motility (peristalsis).

(*a*) **Position.**—In the adult, the stomach will usually be found to the left of the middle line with its length more or less vertical, as seen in Fig. 391, and the various radiograms reproduced, in contrast with the supposed horizontal position described in earlier anatomical teaching. In children up to about the age of eight years, or possibly ten or twelve, and in a few adults, as in the anthropoid apes, the stomach is found in a horizontal position; but in those cases the surfaces commonly referred to as anterior and posterior will be found respectively superior and inferior (proserial and retroserial).

This developmental change is an interesting one, upon which radiology applied to younger subjects may yet throw further light.

For convenience of description and discussion, the stomach is usually spoken of by radiologists as divided into three parts: a first or *pars cardiaca*, a second or *pars media*, and a third or *pars pylorica*.

The first two correspond with the *body* as described by anatomists, and the third with the *pylorus*, two parts distinctly differentiated structurally and functionally.

The extremity of each terminal part is loosely anchored to the posterior body wall by structures attached there, and may for practical purposes be considered fixed in position.

The *cardiac end* is attached by the œsophagus as it passes through the diaphragm; and this junction of œsophagus and stomach, forming the *incisura cardiaca* (as illustrated in Fig. 391), may be taken as normally opposite the upper part of the left border of the *twelfth dorsal vertebra*, or just inside a point on the left costal margin two inches from its sternal end.

The pyloric end may be taken as lying over the *third lumbar vertebra*, where it is loosely fixed by the gastrohepatic omentum and by the vessels and tissues of the cœliac axis.

(The *umbilicus* will usually overlie the following vertebra—the fourth lumbar.)

The *lesser curvature* between those two points is also relatively fixed, but the *greater curvature* is free to move, and great variation is found in its position within apparently normal limits.

The shape and position of the stomach varies with the general build and physique of the individual. Thus (i) a person of robust habit with heavy bones and strong muscles, having

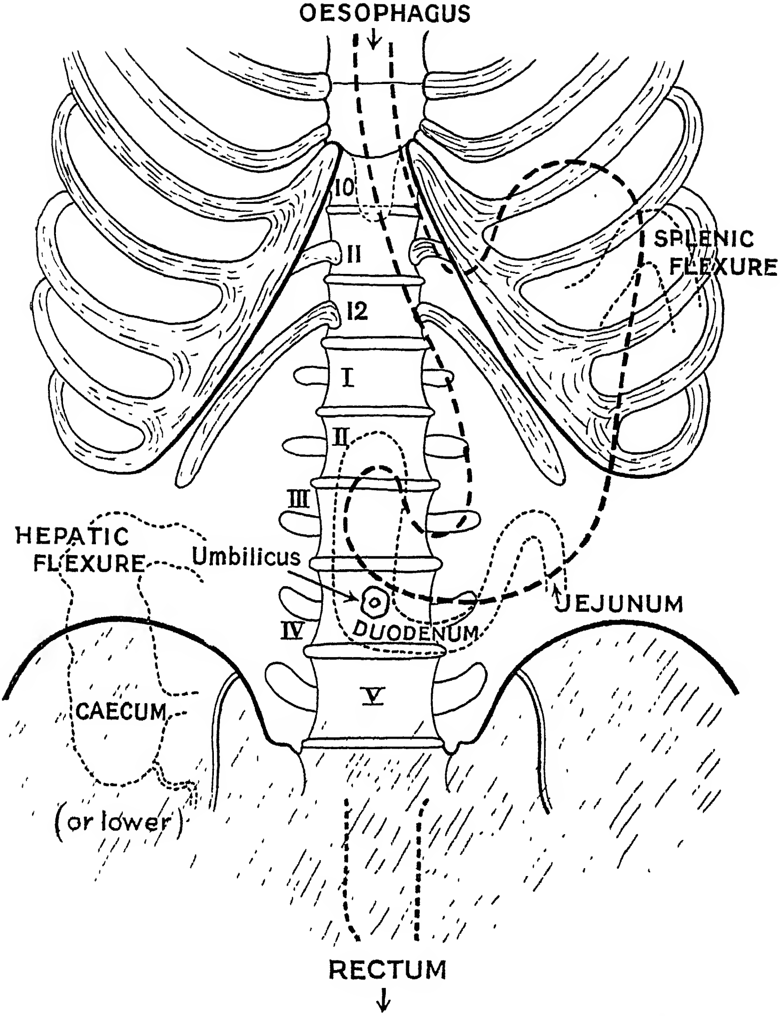
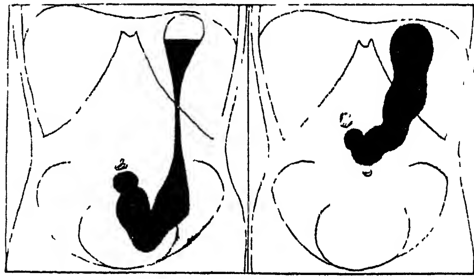


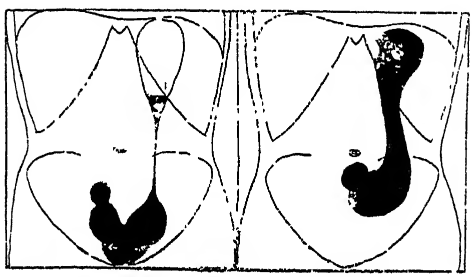
Fig. 391.—LANDMARKS OF NORMAL (OR AVERAGE) STOMACH.

Plate LXVIII.



Vertical. Horizontal.

Fig. 392.—ORTHOSTATIC GASTROPTOSIS.



Vertical. Horizontal.

Fig. 393.—COMPLETE GASTROPTOSIS.

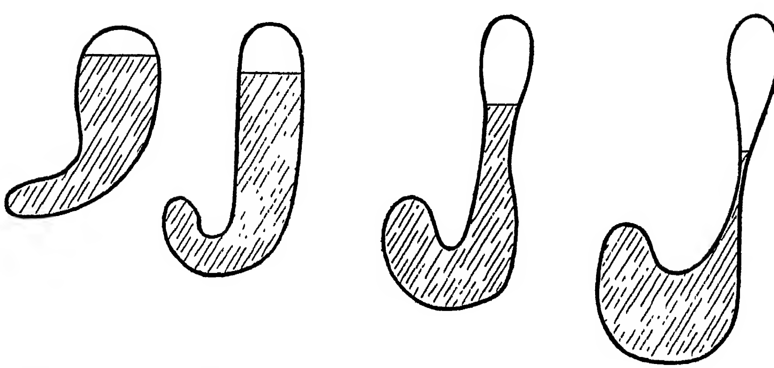


Fig. 394.—TYPES OF X-RAY STOMACH.

Plate LXIX.

a well developed chest with horizontal ribs and obtuse epigastric angle, a person of "*hypersthenic habitus*," will normally have a hypertonic stomach, high in position and more nearly horizontal in direction than average; (ii) by contrast a person of slight build and feeble development, having a long narrow chest with steeply inclined ribs and an acute epigastric angle, a person of "*asthenic habitus*," will normally have an atonic stomach vertically placed and low in position; and (iii) between those extremes an average person of "*normal or sthenic habitus*" will have a stomach intermediate between hypertonic and atonic, like that illustrated in Fig. 391 or in the second example in Fig. 394.

The *lower pole* of the stomach may be expected under normal conditions to lie about the level of the umbilicus, and may be considered as abnormal if it be found more than one inch below the corresponding line joining the iliac crests. The meaning of such abnormality is not always clear, and too much stress should not, in diagnosis, be laid upon it alone.

The usual shapes are described, and classification (as in the succeeding section) constructed, upon observations made with patients in the vertical position, but in estimating the nature and degree of gastroptosis the position and shape of the stomach should be observed also in the *horizontal position*. This point is illustrated in Figs. 392 and 393.

In Fig. 392 the stomach is seen to be able to recover its position in the recumbent posture, although lack of support permits its displacement under the influence of gravity in the erect posture.

In Fig. 393 a further degree of gastroptosis is seen to exist, since the stomach fails to recover its normal position even in the recumbent posture.

(*b*) **Shape and Size.**—The usual shapes seen, and also the size, depend mainly upon the *tone* of the muscular wall of the stomach, also upon the amount of its contents, and partly upon certain secondary factors, such as the degree of abdominal support given to it from below. The relation of the shape and size, as well as position of the stomach to the type of individual under observation, must always be considered in assessing the importance of observed data.

Based upon the factor of tone, a rough classification of shape is illustrated in Fig. 394. Those shapes are based upon observations in the erect posture, in which posture patients

are usually examined. In the horizontal position, especially with the patient on his back, compression of the filled stomach may produce distortion, which must be discounted, but all doubtful cases should be examined in various recumbent positions as well as the vertical.

When empty the stomach is flattened from before backwards, and food is accommodated by a rounding out of this flattening. The cardiac end or *fundus*, projecting upwards under the dome of the diaphragm, is always occupied by air, the lower level of which, in the vertical position, is usually close above the upper edge of the œsophageal opening. The position of this *air cap* naturally varies with the position of the patient.

As the meal commences to enter the stomach, it may be seen from its shadow to form first a funnel-shaped mass under the air cap and then to canalise the body (or pars media) to reach the dependent part of the viscus. The opaque meal in its course downwards may outline the *rugæ* of the stomach wall, and the irregularities of outline produced by those must be identified and recognised as normal appearances. The stomach is usually described as ending at the *pylorus*, in which part of its course the opaque meal appears as a narrow central shadow, about $\frac{1}{8}$ in. broad and normally $\frac{1}{6}$ to $\frac{1}{4}$ in. in length. That part of the tract immediately beyond the pyloric valve is commonly called the first part of the duodenum, but is really more akin to stomach than to bowel, both physiologically and pathologically, and might well be considered as a post pyloric part of the former. Ulcers found there should be referred to as post pyloric rather than duodenal. This is a most important part radiologically, and is known as the *duodenal bulb or cap* or the *pilleus ventriculi*. It seems to act as a reservoir, in which the gastric digestion is completed of successive small amounts of chyme isolated by the pyloric sphincter from the mass of food in the stomach, and attention should be focussed critically on its method of filling, its size, outline and movements.

On account of the upward and backward direction of this first part of the tract, the cap is from the front usually seen somewhat in profile, and when filled appears as a triangular shadow with the pyloric lumen joining it at the centre of its base, as seen in Fig. 395, and also in Fig. 385 on page 446.

Fig. 395.—Opaque Meal Occupying Stomach, Duodenal Cap, Duodenum and Jejunum.

Plate LXX.

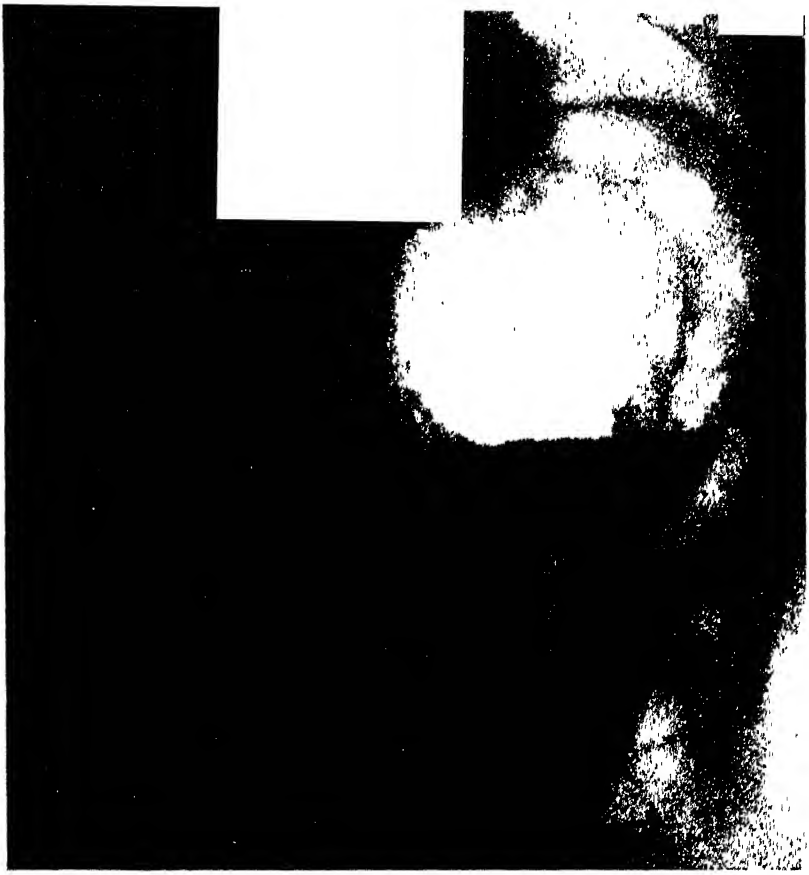


Fig. 396.—"CUP-AND-SPILL" OR "CASCADE" TYPE OF STOMACH.

Fig. 397.—DEFORMITY OF STOMACH PRODUCED BY PRESSURE OF GALL-BLADDER.

Fig. 398.—DEFORMITY OF STOMACH PRODUCED BY ADHESIONS.

Fig. 394 shews typical X-ray shapes, known respectively by the reference names of steer-horn, **J**, or fish-hook shape, whilst Fig. 396 shews a rarer form, which has been noted and referred to as the "cup-and-spill" or cascade type. In this latter figure will be seen two sacs, the upper spilling forward into the lower.

This condition is probably produced by contraction of the oblique fibres of the stomach wall acting alone, and the two sides may act either in unison or independently, so that the "cascade" may be seen to pass from the upper part forward or to either side.

In the case illustrated there was early carcinoma of the pylorus, and the shape frequently appears with lesions in that region, but it may also occur in other conditions, and its significance is not yet clear.

Extrinsic Conditions may *interfere* with the shape of the stomach, as already noted in relation to Fig. 383, in which a cyst in the kidney by pressure produced a puzzling filling defect. Changes may similarly be produced at the pyloric end by pressure of a pathological gall-bladder, as shewn in Figs. 397 and 418, and discussed later on page 500.

Adhesions formed with neighbouring parts, due to disease of those parts, may also produce gross, or minor, changes in the shape of the stomach, as revealed by the opaque meal as in Fig. 398.

(*c*) **Tone.**—Tonic action in the gastric muscle may be said to be a constant function of that muscle which tends to maintain the tubular form of the lumen of the organ and to counterbalance the action of gravity upon its contents.

The shape of a stomach, as already pointed out, therefore depends mainly upon the efficiency of this function, and types of shape are classified accordingly, as in Fig. 394.

The position of a stomach must not, however, be taken to depend entirely upon tone, since organs in positions of extreme ptosis are found nevertheless to be of good tone. Where the lower pole of a stomach is displaced, solely due to *lack of tone* of its walls, the lesser curvature will be found to remain in its normal position, whilst the meal will be seen to collect at the lower pole of the viscus, leaving the middle collapsed and the fundus full of air, as in the right-hand diagram of Fig. 394.

By contrast, a case of pure *gastroptosis* will shew a tubular food shadow, with the lesser curvature lengthened and displaced in correspondence with the remainder of the stomach, as in the diagram of the horizontal position in Fig. 393.

Mixed cases will of course be commonly seen, since the lack

gastroptosis is likely to be accompanied by lack of tone in the stomach muscle, but it is necessary to recognise the independent mechanism of the two associated conditions.

Care must also be exercised not to confuse tone with peristaltic action, as described in the following section.

Tone may, to some extent, be measured by observing the behaviour of the greater curvature in relation to respiratory movements. The fundus necessarily moves with the diaphragm, to which it is closely apposed, but the muscular tone of the stomach wall, exercising its function as a balance against outside influences, so acts that in a strictly normal stomach no movement is noted in the greater curvature. In a low lying stomach with impaired tone some movement will be observed, as also in a highly situated hypertonic organ.

Dilatation, due to lack of tone in a stomach, should be differentiated from the similar condition, more properly so-called, met with in pyloric obstruction. In the former the stomach is uniformly enlarged with a considerable sagging of the organ, whilst peristalsis will be feeble or absent. In pyloric obstruction the enlargement affects mainly the greater curvature at the pyloric end, producing an "undershot" appearance of that region, whilst the stomach will be in a high position, and active peristalsis will probably be noticeable.

Fig. 399, due to obstruction, if compared with the atonic form shewn in Fig. 394, will shew the contrast of the two conditions.

(*d*) **Motility** (*peristalsis*).—The degree of motility and the consequent rate of emptying of the normal stomach depends upon a number of physiological factors, and may differ widely under varying conditions within normal limits. The time of emptying will be discussed later in relation to retention as indicating pathological interference, but much may be learned from screen observation of the actual movements of the stomach. As the opaque meal enters the stomach its stimulus sets up peristaltic waves, which may be first noted at the pyloric end in a deepening of the incisura angularis and an opposite depression in the greater curvature. Those depressions move slowly towards the pylorus, where they disappear, to be followed by another wave commencing in the same region as the first or possibly higher up on the pars media. Later waves may be seen arising at the cardiac end and sweeping along the greater curvature, but they are not often discernible on the lesser curvature except at the lower end. (See Fig. 400.)

Fig 399 —STOMACH DILATED BY OBSTRUCTION AND WITH FEEBLE PERISTALSIS.

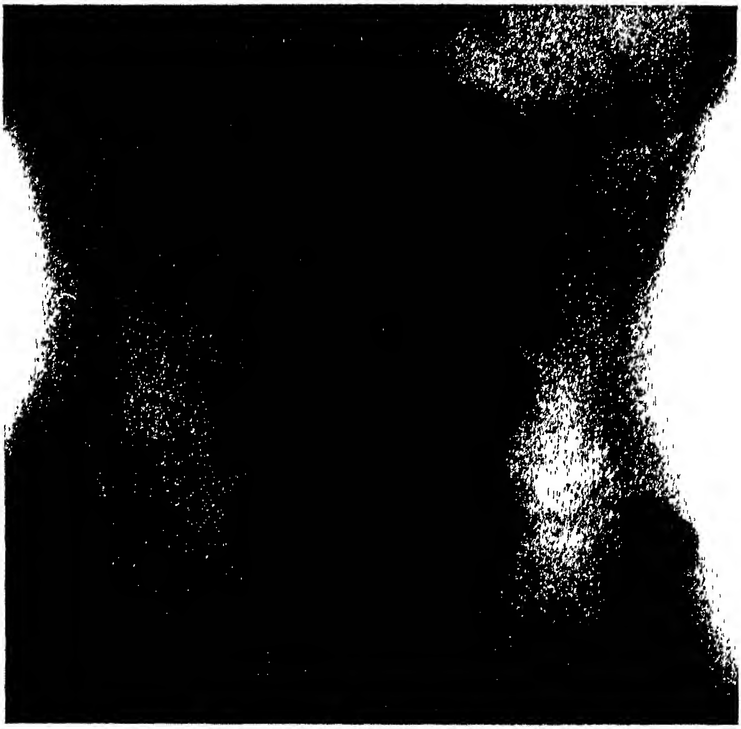


Fig. 400.—STOMACH SHEWING VERY ACTIVE PERISTALSIS.

Plate LXXII.

The cardiac end never shews very active peristalsis, and seen thus seems to act more as a reservoir, from which the food passes into the active pyloric end, sometimes referred to as "the mill."

The force of peristaltic waves, as indicated by the depth of the depressions noted, may vary somewhat in different individuals and in the same individual under varying conditions—many of them psychological; but under normal conditions their character and periodicity, quoted as about three per minute, is fairly uniform.

They are more readily detected in the hypertonic type of stomach, and much less readily in the atonic type, but although tone and peristaltic activity seem commonly to vary in consonance, the two must be recognised as independent functions of the gastric muscle.

The onset of peristalsis may be delayed for various reasons, and massage of the stomach will usually set it in action, but this response is only temporary. Peristalsis is early interfered with by pathological conditions affecting the stomach, and it must be observed carefully in all cases, as *hesitation* or *inhibition* may be the only sign of a lesion causing definite symptoms.

In the duodenal cap a periodical peristaltic contraction may also be noted, which passes the food rapidly through the duodenum into the jejunum, which further part of its excursion will be noted later.

Rate of emptying of the stomach has been variously estimated and, on account of its being so readily influenced by extrinsic factors such as fear, hunger, etc., it is largely discounted by some radiologists as an observation of import. Some variation will also occur with variation in the composition and consistency of the meal employed. A normal stomach, if its movements be not inhibited by any of the influences mentioned, will empty itself of a semi-solid meal containing 10 per cent. of a bismuth salt in two to four hours; if barium be substituted the time is reduced somewhat, but for estimation of retention the higher figure of four hours may be taken for a general normal limit. To allow for possible interferences of a non-pathological nature, this limit is commonly extended to six hours, after which time retention of the opaque meal in the stomach of an amount equal to, or exceeding, one quarter of the total amount is considered pathological, or at least very suggestive of a pathological condition.

The times at which other known points are reached should also be noted and, in that connection, it may be taken that normally a bismuth meal should, after its ingestion, render

the cæcum visible in about $4\frac{1}{2}$ hours
,, hepatic flexure ,, $6\frac{1}{2}$,,
,, splenic ,, ,, 9 ,,
,, rectum ,, ,, 18 to 24 hours
and the tract should be empty in 48 hours

(2) **Gastroptosis,** when present, is plainly evident from the position of the lower pole of the stomach as defined by the shadow of its opaque contents, but considerable degrees of displacement seem to be possible within the normal limits of adequate function.

The necessity for observation in the recumbent, as well as the erect, posture has already been pointed out in p. 457, and a distinction between displacement and lack of tone is drawn on p. 461.

A stomach shewing a considerable degree of ptosis may yet retain good tone, and its time of emptying be little, if any, prolonged; this time must therefore be observed, or the converse retention of contents after a stated interval, before any opinion may be expressed as to functional condition.

The pylorus, as a rule, retains its normal position, but may in odd cases also shew some degree of ptosis, being found as low as the fifth lumbar vertebra, but even then evacuation may not be unduly delayed.

(3) **Gastric Ulcer** may be diagnosed with a facility and certainty dependent upon the extent to which the stomach wall is involved.

(*a*) A **Simple Ulcer** involving mucous membrane only, or a *diffuse callous ulcer*, may be diagnosed by inference from reflex appearances, but no direct evidence of their presence should be expected.

The reflex appearances that may be produced are those of spasm in the body or at the pyloric end, as in Figs. 401 and 402, or a constriction of the body of the stomach due to spasm of a band of circular fibres producing a so-called "hour-glass contraction." This spasm or constriction may be temporary in nature, relaxing under the influence of massage or upon administration of atropine. If the ulceration be followed by formation of scar tissue that may contract and form a permanent constriction, which will be shewn by a corresponding change in the outline of the opacity, as shewn in Fig. 403 opposite. Even to the stage of *perforation* such an ulcer may remain unrevealed by direct evidence, but adhesions to, and penetration of, an adjoining organ may produce conditions which facilitate detection.

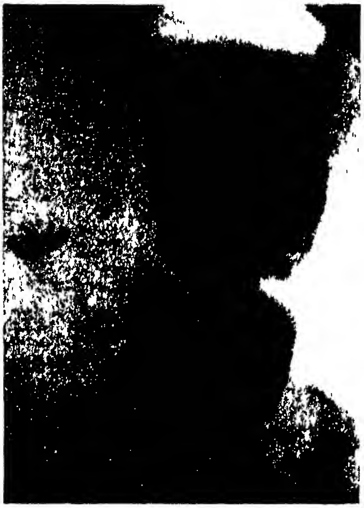


Fig. 401.

Fig. 402.

TWO CASES OF PERSISTENT REFLEX SPASM SUGGESTING ULCER.

Fig. 403.—CONSTRICTION CAUSED BY ULCER.

Fig. 404.—SPASM AT SITE OF ULCER, FOUND AT OPERATION.

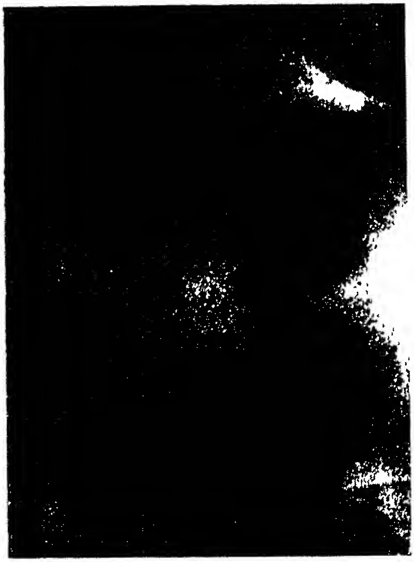


Fig. 405.

Fig. 406.

PENETRATING ULCERS, SHEWING "NICHE AND NOTCH."

Fig. 407.—SHADOW PERSISTING AT SITE OF ULCER.
(From same case as 405.)

Fig. 408.—RESIDUE SHADOW ON CRATER OF ULCER.

Plate LXXIV.

(*b*) A **Penetrating Ulcer** gives direct evidence of its presence if technique be successful in securing entry of a portion of the opaque meal into its depression.

For this purpose the first portion of the meal may be made specially fluid, and the stomach manipulated immediately after entry of the fluid, so that it may be spread well over the inner surface of the viscus, and into any depressions or irregularities that may exist.

An ulcer may thus be diagnosed from the following appearances collectively: (i) by the filling of its crater as seen in profile, giving the appearance of an *opaque projection* outside the general contour of the stomach wall—a so-called "niche" opposite a "notch," as in Figs. 405 and 406; (ii) by the *persistence* of this projecting shadow after that part of the stomach is otherwise empty, as in Fig. 407, from the same case as Fig 405; (iii) by the presence of an air bubble marking the upper limit of the crater contents, as seen in Fig. 406.

Such an ulcer is usually found on the lesser curvature, but may occur on the greater curvature, and the patient may have to be rotated under screen observation so as to get the crater in profile. Seen in surface view, the filled ulcer will appear as a dark shadow remaining after the affected part of the stomach is empty of other opaque contents, as in Fig. 408, but the appearance may be indefinite and at times somewhat confusing.

In addition to those three direct signs of perforating ulcer, there will probably appear (iv.) a *constant area of contraction* of the stomach wall opposite the site of the ulcer; if this is accompanied by a pseudo hour-glass contraction the band of constriction will be broader than found with simple ulcer; (v) *peristalisis* will be feeble, and the waves will usually appear arrested as they pass the site of the ulcer; and (vi.) the *time of emptying* of the stomach will be correspondingly delayed.

The *pyloric shadow* may be *displaced* to the left, and the greater curvature assume a position more perpendicular than usual.

Tenderness over the site of the ulcer is quoted by many observers, but this is of doubtful origin and significance.

If the liver be involved in the ulcerative process the crater shadow will be seen to move with respiration, but if pancreas or spleen form the base of the ulcer no such movement will be apparent. (X-ray appearances of an ulcer are further discussed, in relation to the duodenum, on page 476).

(4) **Hour-glass Stomach** may, as noted above, be spasmodic in nature and therefore temporary in duration, which condition has come to be spoken of as *pseudo* hour-glass. This is usually due to reflex action produced by a simple, and possibly very small, ulcer on some part of the stomach wall, but the condition gives no indication of the site of the ulcer (although that is usually on the lesser curvature). Chronic appendicitis, gall stones or duodenal ulcer may also produce a similar spasmodic condition. Electrical stimulation of the region of the latter condition was proved by Barclay to produce a definite spasm of the pars media of the stomach.

Massage of the stomach contents upwards may dilate the temporary constriction or, upon repeated observation, it may be found to have disappeared. Only after such massage and frequently repeated inspection may the condition be reported as *permanent* or *true* hour-glass contraction. This latter condition may be due to contraction of scar tissue accompanying or following ulceration, as in Fig. 409, or may be caused by the constricting ingrowth of a malignant tumour, as partially seen in Fig. 411. Apart from the direct appearances of the latter, as described in a succeeding section, the main feature of differentiation is in the rate of emptying of the stomach ; the contraction due to scar tissue produces a variable but distinct delay in this process, whilst malignant invasion does not usually affect it or may at times hasten it. As compared with a spasmodic contraction an organic constriction is less definitely conical in its upper part, and part of the upper sac may be seen to sag below and to the left of the entrance to the constriction.

(5) **Pyloric Ulceration** is hard to diagnose from X-ray appearances; evidence of its presence being almost entirely indirect. In this respect it resembles gastric ulcer, and may be hard to differentiate except where secondary direct signs may indicate the location, as described later with reference to post pyloric ulcers. Resultant scars and contraction may produce definite obstruction with its diagnostic signs of delay and dilatation. Fig. 410 reproduces one of a serial, shewing a persistent residue at the site of the pylorus, where at operation an ulcer was found.

Fig. 409. HOUR-GLASS STOMACH.

Fig. 410.—RESIDUE SHADOW AT SITE OF PYLORIC ULCER.

Plate LXXV.

Fig. 411.—CARCINOMA OF STOMACH WALL.

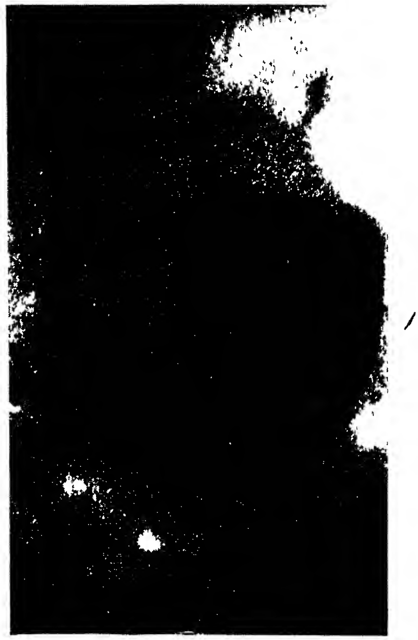


Fig. 412.—CARCINOMA OF PYLORUS.

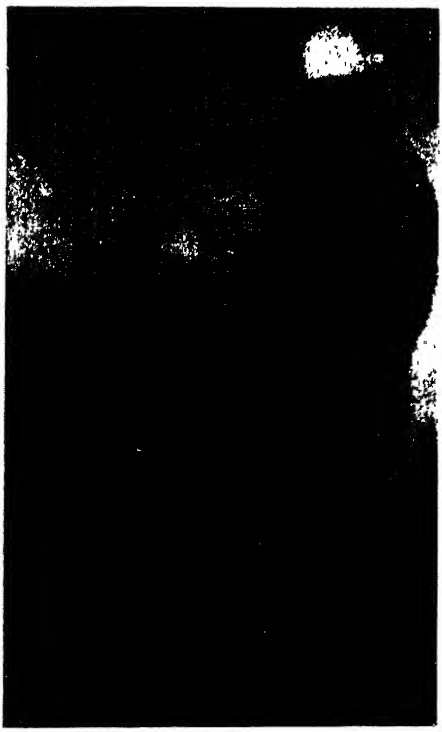


Fig. 413.—CARCINOMA OF LOWER POLE.

Fig. 414.—CARCINOMA OF ENTIRE PYLORIC SEGMENT.

Plate LXXVI.

(6) **Carcinoma,** in its earlier stages, infiltrates the stomach wall so as to produce localised rigidity interfering with the regular filling out of the viscus, as noted in the formation of the normal shadow. As revealed by an opaque meal, the *shape* appears *irregular*, as in Figs. 411 and 413, and the *size* usually *reduced* (except for secondary dilatation), whilst the *movements* are *reduced* or *inhibited* according to the extent of invasion.

Further growth definitely encroaches upon the cavity of the viscus, and the shadow of the opaque contents shews a corresponding diminution and defect. Similar appearances may be produced by other causes, such as spasm or external pressure, but *the differential point* to be noted in deficiencies produced by presence of new growth is their *permanence*. It is in detection of this factor that the rival methods of screen observation and serial films claim relative superiority.

By whatever method the observations may be made, great care must be taken to eliminate the possibility of temporary spasmodic contraction before malignancy is diagnosed.

(*a*) Where the growth takes the form of *widespread infiltration* of the stomach wall, an outline suggesting a hypertonic organ is produced. When this is extensive the stomach presents the appearance of a rigid canal with patent pylorus, and very rapid emptying of the viscus may be noted.

(*b*) If the growth originates at the *cardiac end*, stenosis of the lower end of the œsophagus may be found, as shewn by delay in admission of the opaque meal, which will form a narrow tortuous shadow as it enters the stomach from a dilated pouch of the œsophagus above the growth. No obstruction or retention will, however, be observed in the stomach itself.

(*c*) If the growth is at the *pyloric end*, an absence of opaque shadow will be noted in that area, as in Fig. 412, and the lower limit of the shadow of the body contents will be irregular; the right hand end of the mass being roughly conical in shape instead of rounded, and probably shaded by persistent irregular appearances like "finger-mark" depressions. With a further advanced growth, the lumen may be represented only by a narrow irregular strip of shadow in place of the normal bulbous mass, as in Fig. 414. A broad dense shadow in the region of the fundus may reveal *dilatation* above the growth, and a shortening of the lesser curvature may give the pylorus a higher position.

In all cases of new growth the regular course of *peristalsis* will be more or less disturbed and may be altogether inhibited.

(*d*) The following table of differential appearances (modified from one given by Dr. Cole, of New York) may serve as a guide towards a decision in doubtful cases:—

Malignant	Non-Malignant	
	Spasm	Organic.
(i) *Lumen* of affected part, as defined by the filling opaque meal and its resultant shadow, is *encroached upon* (*e.g.*, "pipe-stem" appearance at pylorus); and this constriction is *constant* in size, shape and position.	Lumen may *change* in position.	Lumen may *vary*, but never completely relaxes or contracts.
(ii) Area of constriction is relatively *wide*.	Area narrow and ring-like.	Area varies
(iii) *Peristalsis absent.*	Peristalsis present in either or both segments.	Peristaltic contractions wider than normal.
(iv) Area of invasion shows indentations like finger prints.	Area of invasion smooth.	Area of invasion may have sharp or serrated margins but no finger prints.
(v) *Rugæ* are *absent* in area of invasion.	Rugæ are normal.	Rugæ are unusally distinct.

(7) **Syphilis** affecting the stomach may produce appearances closely resembling those described as due to carcinoma, and differentiation must be made by reference to the patient's clinical history and condition. So considered, as in other syphilitic lesions, the physical defects suggested by the radiogram will be out of proportion to other symptoms, and the patient's general condition better than would be possible with a malignant lesion of similar extent.

(8) **Linitis Plastica,** or "leather-bottle stomach," is a condition of some clinical obscurity and ætiological confusion, but its recognition radiologically may be clear enough. The appearances seen resemble those described above as in a diffuse infiltrating carcinoma—a small organ with smoothly outlined shadow, high in position, and shewing limited, or no trace of, peristalsis.

In rare cases, with obstructed pylorus, there may be some degree of dilatation and delay in emptying, but usually the pylorus is patent and emptying is very rapid. In the process of filling, or under palpation, a striking lack of flexibility will be noted. As to the nature of the condition, whether fibromatous, cancerous, or syphilitic, radiology makes little or no suggestion.

IV. THE INTESTINES

Duodenum, *small* and *large intestine*, are all outlined in sequence by the progressing opaque bolus, and much interesting study of the position and movements of those organs is made possible by this method of observation.

Here, again, the variations possible within normal limits must be borne in mind in making a diagnosis.

Visceroptosis and *stasis* are easily observed and noted as due to *obstruction*, or possibly *kinks* at different points. Before deciding that either of the latter conditions exist, the effect of massage and manipulation should be tried, as tending respectively to relieve spasm and to alter position of the bowel; whilst several examinations, at intervals of some days, should always be made before any condition is diagnosed as suggesting need for operation.

The fixed points in the course of the intestines are indicated in Fig. 391, on page 455, but between those points there is great mobility, and the hepatic flexure may vary in position somewhat. Seldom does it appear as high as the costal margin, although it is commonly represented there in anatomical diagrams.

(1) **The Opaque Enema.**—For observation of the great intestine, and possibly the terminal ileum, an opaque enema should be administered in addition to the meal already described for stomach observation. To shew up this part of the tract one of the more solid meals will serve best, but additional information will usually be obtained from observation of the enema.

The enema should consist of an emulsion of barium sulphate in water or milk, one proportion used being 250 grms. with 500 c.c. of mucilage of acacia in 2 litres; another is given on page 439 (No. 3 mixture).

This mixture, at body temperature, should be run slowly into the rectum from an elevated can, and its progress should be observed by the screen until it reaches, and possibly passes, the ileocæcal valve. This may take about ten minutes, but the process should not be unduly hastened. Figs. 420 and 421, on page 483, shew appearances commonly seen in normal colons.

(2) **The Duodenum.**—This part at its commencement, known as the cap or bulb, is movable, but in its further course it is firmly fixed. The cap is well shewn in Fig. 395, on page 459, which is a front view, but to obtain a good view of the pylorus and duodenum the patient may have to lie on his right side or on

his face; if in the erect posture he may be rotated into the corresponding positions.

Under normal conditions the duodenum is the most active part of the digestive tract, as may be seen if special efforts are made to keep it filled by massaging the opaque meal through the pylorus. Very little is seen of the meal as it is hurried through, if its progress be uninterrupted, and there is therefore little chance to study the contour or movements of the duodenum, beyond the bulb or cap already described on page 458. As there mentioned, this first part of the duodenum is closely allied in structure and function to the stomach, and the region is thus commonly referred to as post-pyloric rather than duodenal. It is in this region that duodenal ulceration is most commonly met with, and direct radiological evidence should be sought in deformities of the "cap" and sphincter, whilst indirect evidence should also be looked for.

(*a*) **A Simple Ulcer,** as in the stomach, is not likely to produce any direct signs, but, in the presence of suggestive symptoms, indirect evidence may be found in the normal or *diminished emptying time* of the stomach as contrasted with the delay accompanying gastric or pyloric ulceration. The stomach will appear *hypertonic* and will show increased peristalsis; the position of its lower pole may be well above the intercristal line, and food will be seen to leave the stomach more frequently than usual.

Retention of the opaque meal in the second or third part of the duodenum is a further characteristic sign; this being due probably to spasm of the duodeno-jejunal junction or to diminished peristalsis of the affected region.

(*b*) **A Penetrating Ulcer,** as in the stomach, may be diagnosed by direct evidence produced by the filling of its crater by the opaque meal and retention of a local shadow after the main part of the meal has passed, or by the projection of its indurated edges into the opaque filled lumen of the cap. Fig. 415 shews such retention in a crater in the situation of the duodenal cap.

Short of such detailed evidence, a post-pyloric ulcer may be diagnosed from *constant deformity of the cap or sphincter,* as produced by induration or by cicatricial contraction accompanying, or resulting from, ulceration. The deformity produced may be due to projection of the induration into the lumen, this appearing as a lighter shadow contrasted with the dense shadow of the opaque contents, as in Fig. 416, or may be due mainly to cicatricial contractions, or adhesions, as suggested by Fig. 417.

Fig. 415.—Retention Shadow in a Post-pyloric Ulcer.

Fig. 416.—Filling Defect in Duodenal Cap due to Induration of Post-pyloric Ulcer.

Fig. 417.—Filling Defect in Duodenal Cap due to Cicatricial Contractions at Site of Ulcer.

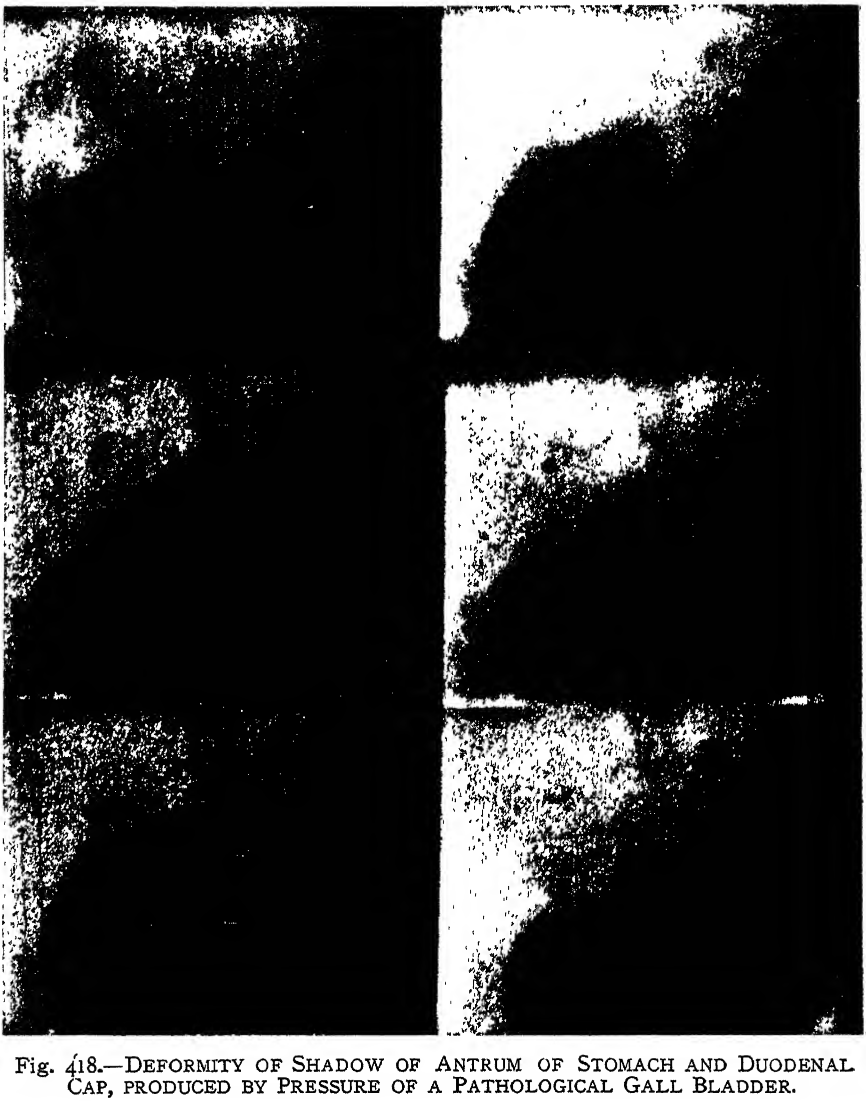


Fig. 418.—Deformity of Shadow of Antrum of Stomach and Duodenal Cap, produced by Pressure of a Pathological Gall Bladder.

Plate LXXVIII.

In the former case the evidence points directly to the lesion producing it, and a profile view of the opaque filled crater and retention therein after the main lumen has cleared will place the diagnosis beyond doubt. If the ulcer crater be situated so that only a surface view of it may be obtained, its opaque contents will appear as an indefinite deeper shadow, and might possibly be confused with flecks of opaque salt adherent to the mucous membrane, see Fig. 408, on page 468. Similar retention may sometimes occur in pouches due to puckering of the duodenal wall between bands of contracture or adhesion, so that care is required in interpreting doubtful appearances, and all the signs, direct and indirect, may have to be carefully considered and correlated with clinical symptoms before a definite diagnosis be attempted.

The outline of the cap may be further distorted by adhesions formed with neighbouring parts, and the same adhesions may produce secondary conditions in those other parts of which the symptoms may be more prominent than the primary.

Reflex effects on the stomach have already been mentioned; other parts likely to be involved are the hepatic flexure and the duodeno-jejunal junction.

Adhesions in the latter region may produce dilatation of the descending and horizontal parts of the duodenum, similar to that produced by obstruction caused by the root of the mesentery (described by Wilkie, and known as "chronic duodenal ileus"), or by ulceration in the posterior wall of the stomach.

If the ulceration affects the pylorus, *dilatation of the stomach* will ensue with the characteristic undershot appearance of the lower end of the greater curvature, as in Fig. 399.

(*c*) **Spasm of the Duodenal Cap** may be produced reflexly by several extrinsic conditions such as appendicitis, gall stones or renal calculi. The deformity due to such spasm will be seen to vary, and at times will be absent in a series of observations, or it may be dismissed by administration of belladonna. One normal appearance will, of course, definitely negative all suggestion of abnormality in other views, so that a set of serial views, taken as described on page 444, is here of great value.

Fig. 385, on page 446, reproduces such a serial, in which one normal appearance of the cap conclusively contradicts the appearance of abnormality in the others.

(*d*) **Extrinsic Deformity of Cap.**—Constant deformity may, however, be produced by conditions in neighbouring parts, particularly by adhesions or pressure due to a pathological gall bladder, as illustrated in Fig. 418. Such adhesions usually produce a more extensive interference than post-pyloric ulceration, and contracture of the adhesions may produce a displacement of the stomach towards the right side, but in the absence of direct evidence of an ulcer the differentiation may be very difficult and perhaps impossible. Fortunately, the call for differentiation is not urgent, as the conditions revealed in any case demand surgical interference.

Pressure effects of a gall bladder are sometimes characteristic, the cause of the deformity being indicated by a sickle-shaped indentation of graded shadow impinging upon the dense main shadow of the pyloric end of the stomach and of the duodenal cap. This is referred to by Dr. George, of Boston, as a "half-shadow," and pronounced by him to be pathognomonic of an abnormal gall bladder, even in the absence of direct signs of change in that organ.

Several of the serial views reproduced in Fig. 418 shew such an appearance, which is further discussed on page 500.

If examination of the duodenal cap fails to supply definite explanation of symptoms complained of, and referred to that region, the further parts of the intestinal tract should always be examined; and, conversely, when symptoms are referred to further parts, inspection of this important region should never be omitted, since in the cap may be found reflex signs pointing to other origin, or direct evidence of an original lesion causing, secondarily, the symptoms complained of.

(*e*) **Duodenal Obstruction** may be made evident by *delay* in passage of the opaque meal and, directly, by a *constricted area* of the lumen compared with a *dilated portion* proximal to it. Such constriction is usually due to *spasm* or *scar contraction* arising from a post-pyloric ulcer or inflammatory disease of adjoining organs, notably the gall bladder.

Carcinoma is rare in the duodenum, and when present usually affects the region of the ampulla of Vater.

Except in the post-pyloric region already described, in which region ulceration usually appears, it is not possible to differentiate the causes of obstruction, since the presence of valvulæ conniventes gives the contour of the shadow a ribbed or serrated appearance which defies attempts at finer definition.

Normally, however, the duodenum passes on contents almost as fast as it receives them, so that any appreciable retention of

opaque mass in that part of the tract at once suggests obstruction from some cause.

The retention may mainly appear in the stomach, so, if no appearances of an explanatory lesion are found there, the duodenum should be suspected.

(3) **Jejunum.**—After leaving the duodenum the opaque meal becomes scattered, and this, with valvulæ conniventes, gives the shadow an indefinite feathery appearance with little or no localising definition.

Signs of obstruction, as in the duodenum, is the only in-

Fig. 419.—Dilatation of Jejunum and Ileum due to Malignant Obstruction in Distal Section of Ileum.

formation likely to be elicited, but no mass of retained opacity should here be expected. There may be a distinct residue proximal to the site of constriction, but more likely the main appearance will be that of loops of *bowel distended with gas and fluid*, as in Fig. 419, which is from a case in which a malignant constriction was found in the ileum. In such distended loops active peristalsis and reverse peristalsis may be noted.

In a case of definite obstruction the dilatation of the bowel with retained barium, long after that part should normally be empty, will at once furnish a diagnosis so far as the physical condition is concerned, but little, or no, evidence need be anticipated to define the cause of that condition. If opaque contents of any considerable amount are noted in the jejunum after six hours, some explanation must be sought.

Carcinoma is more common here than in the other two parts of the small intestine, and the obstruction noted may be due to that or to adhesions from neighbouring inflammatory conditions.

(4) **Ileum.**—In its upper part the ileum shares the characters of the jejunum, but at its lower part the valvulæ conniventes have disappeared, and a shadow of about a finger breadth in diameter, but with unbroken contour, outlines its course. That course is very variable, ptosis being very common and the whole length of the ileum being very mobile. It is thus hard to define it sometimes in the screen picture, but careful palpation under observation will usually suffice to distinguish it.

After eight hours little, if any, residue of the opaque meal should be evident, even in the terminal part, if the upper parts of the tract have passed on the meal within normal limits of time.

Obstruction will produce in the higher parts the signs noted in the preceding section, but as this obstruction occurs most commonly at or near the terminal junction with the cæcum, the local constriction with proximal dilatation will usually be easily discernible. This dilatation may be very marked and retention of contents may be noted for long periods, but varying degrees of obstruction will naturally be accompanied by corresponding degrees of visible effect.

Diseased appendix, *tuberculosis* and *carcinoma* are the common causes of the obstructive condition.

Ileal stasis has been a much discussed subject in recent years, and in its discussion X-ray appearances have been quoted, and their interpretation made to bear a significance which, in many cases, was unwarranted. The determination of stasis is based upon the time after which no further opaque mass is detected in the ileum, but this must naturally vary with the rate of emptying of the stomach.

Seven hours is undoubtedly too short to quote for a maximum time for normal clearance of the ileum and, with any time limit, delay here can only be considered as a relative factor of little isolated importance. In all cases this factor must be considered in association and correlation with other signs and symptoms, when it may convey valuable suggestions to the physician or surgeon.

In presence of appreciable delay, suggesting ileal stasis, evidence should be sought of a possible cause, such as :—

(*a*) Incomplete emptying of cæcum.
(*b*) Insufficiency of ileocæcal valve.
(*c*) Kinks of the terminal ileum produced by membranes, adhesions, etc.
(*d*) Chronic appendicitis, with or without adhesions. (See Fig. 428, on page 489).

(5) **Ileocæcal Valve.**—*Obstruction* at this point has already been noted in the preceding section, but it would appear from X-ray observations that *incompetency* of the ileocæcal valve is more common than was otherwise suspected. An opaque enema will reveal this incompetency when present, and such a condition may explain many cases of ileal stasis.

(6) **The Large Intestine,** as revealed by the opaque meal, shews great variation in size and position.

(*a*) *Position* (see Fig. 391, on page 455).—The *cæcum* may assume an extra- or intra-pelvic position, from which the *ascending colon* normally passes upwards and backward to the

Fig. 420.

Fig. 421.

OPAQUE ENEMATA, SHEWING VARYING POSITION OF TRANSVERSE COLON.

hepatic flexure. This at its highest point usually lies about 1 in. above the intercristal line, but it may shew considerable degrees of ptosis without any apparent disturbance of function. The *transverse colon* usually follows a decidedly curved course across the abdomen, sagging at its middle below the intercristal line and rising in its distal third to the *splenic flexure*, which is firmly held up under the left diaphragm. This distal limb, as seen in Fig. 421, frequently overlies the *descending colon*, which passes downwards to the brim of the true pelvis, where it merges into the *sigmoid flexure*, which part is specially variable in shape and position. The *rectum* is fixed in position, but varies enormously in shape and size according to its contents.

(*b*) **Movements.**—The movements of the colon, as revealed by opaque meal or enema, are somewhat hard to analyse, but two main types of movement may be recognised:—

(i) *Gross longitudinal peristalsis* seems to be the chief mechanism by which food is moved along the bowel, although it is not often observed. Occurring only at long intervals, it is computed that five or six such actions suffice for the passage of a meal through the length of the colon.

Fig. 422.—SEGMENTATION OF COLON DUE TO CIRCULAR FIBRES. (See Figs. 423 and 424.)

(ii) *Haustral or segmentation* movements, with alternate contraction and relaxation of the circular fibres, occur more regularly and produce the characteristic segmented appearance seen in all radiograms of the large intestine, as in Fig. 422. This segmentation disappears over a large area preceding a longitudinal propulsion, as seen in Fig. 423, and the large smooth bolus is then seen to move rapidly along the bowel for a considerable distance, after which segmentation reappears in the mass thus moved. Fig. 424, taken a few minutes after Fig. 423, shews the new position of the transferred mass.

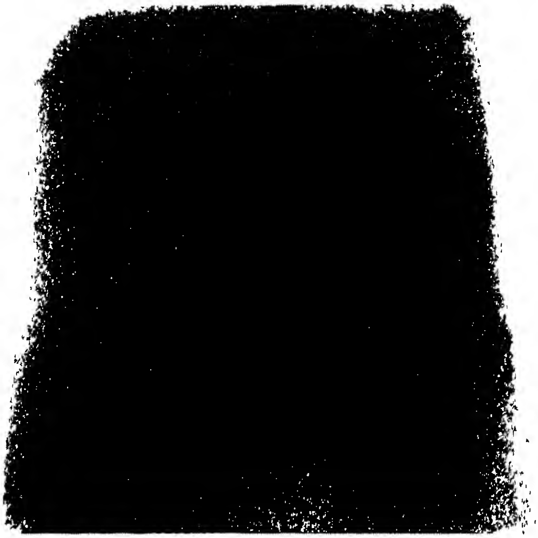


Fig. 423.—ABSENCE OF SEGMENTATION PRECEDING LONGITUDINAL MASS MOVEMENT.

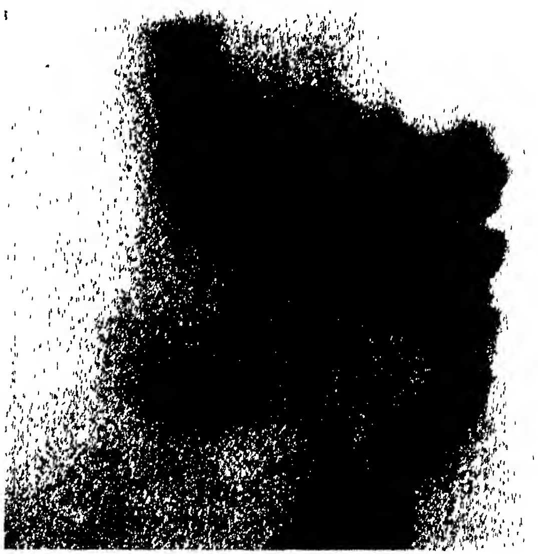


Fig. 424.—ALTERED POSITION OF INTESTINAL CONTENTS A FEW MINUTES AFTER FIG. 423.
(Compare with Fig. 422, taken before movement.)

Fig. 425.- IDIOPATHIC DILATATION OF COLON (HIRSCHSPRUNG'S DISEASE)

(*c*) **Abnormalities.**—The cæcum and ascending colon shew great variation, marked degrees of *dilatation* occurring in many cases of constipation and equally marked degrees of *ptosis*, but how far such observed abnormalities may be considered as causes or effects of pathological conditions seems yet unsettled.

Congenital Idiopathic Dilatation of the colon (so-called Hirschsprung's disease) produces a striking appearance, as reproduced in Fig. 425. Apart from such definite abnormalities considerable enlargement of the lumen of all parts of the large intestine to accommodate its contents, and very definite ptosis, accompanying the free mobility of the parts, are noted in many cases in which the function of the tract seems normal. Undue *mobility* of the cæcum is sometimes quoted as of pathological significance, but in the absence of adhesions binding it in its abnormal position the effect of such mobility is hard to define. *Immobility* is probably of more direct significance, suggesting a diseased appendix, as discussed later. The above conditions should be observed and noted so that they may be correlated with other findings, clinical and radiological.

Colonic stasis is similarly a relative condition, of which the X-ray evidence is of value only in correlation with other observations.

(*d*) **Obstruction** will be indicated by findings similar to those described in the small intestine, namely, *delay* in passage of the opaque meal, a *constricted area* of the lumen and a *dilated portion* proximal to the constriction. A corroboration of those findings should be sought by observing the passage of an opaque enema. This should pass all the way freely to the cæcum, unless prevented by organic constriction, pressure, or spasm. The two latter may be eliminated, but it is always difficult to decide the nature of the lesion producing a constriction.

(*e*) The **appendix** may frequently be seen outlined by its opaque contents, and important information may be gained as to its condition. A semi-fluid meal, after purgation by castor oil, probably serves best to secure such views as are reproduced in Figs. 426 to 429, and examination is best made with the patient lying down.

If the appendix is not at first visible on the screen, change in position of the tube and manipulation of the overlying cæcum and ileum may reveal it, as seen in Fig. 426. Its shape, size, and position should be noted, and the effect of pressure directly over its shadow should be observed.

Normally, an appendix may be expected to *fill and empty* with, or following, the cæcum, and failure so to fill is suggestive of pathological change. On account of its position, however, it may not always be easy to see an appendix when so filled, so that its non-appearance on screen or films must always be interpreted with caution and only in association with other related findings.

Irregular filling with constant defect is suggestive of pathological concretion, and a *tortuous course* is suspicious, but only relatively so. *Mobility* of a visible appendix should be tested by manipulation, and *fixation* considered a definite sign of disease, especially when the adjoining portions of the cæcum and ileum are likewise fixed, but definite proof of fixation is not always easy.

Pain may have been previously noted over the appendix region, but, guided by the screen, it may now be settled whether the pain is in the appendix itself by noting whether the painful pressure point follows the appendix when manipulated into various positions.

Tenderness on pressure over the site of a visible appendix, and not elsewhere, is definitely diagnostic, especially if associated with undoubted fixation.

A *residue* in such an appendix after the cæcum is empty, as in Fig. 429, furthers the suspicion of disease, although alone the sign may be very indefinite as evidence.

Many *indirect* or reflex signs in other parts of the gastro-intestinal tract may be ascribed to a diseased appendix, and their presence taken as suggestive of such a condition, but only when thorough search has eliminated the possibility of other and more direct causes should any importance be placed on such signs.

Fig. 426.—Appendix Displayed by Manipulation.

Fig. 427.—Appendix Adherent in Pelvis.

Fig. 428.—A Visible Appendix and Ileal Stasis.

Fig. 429.—Residue Shadow in Appendix.

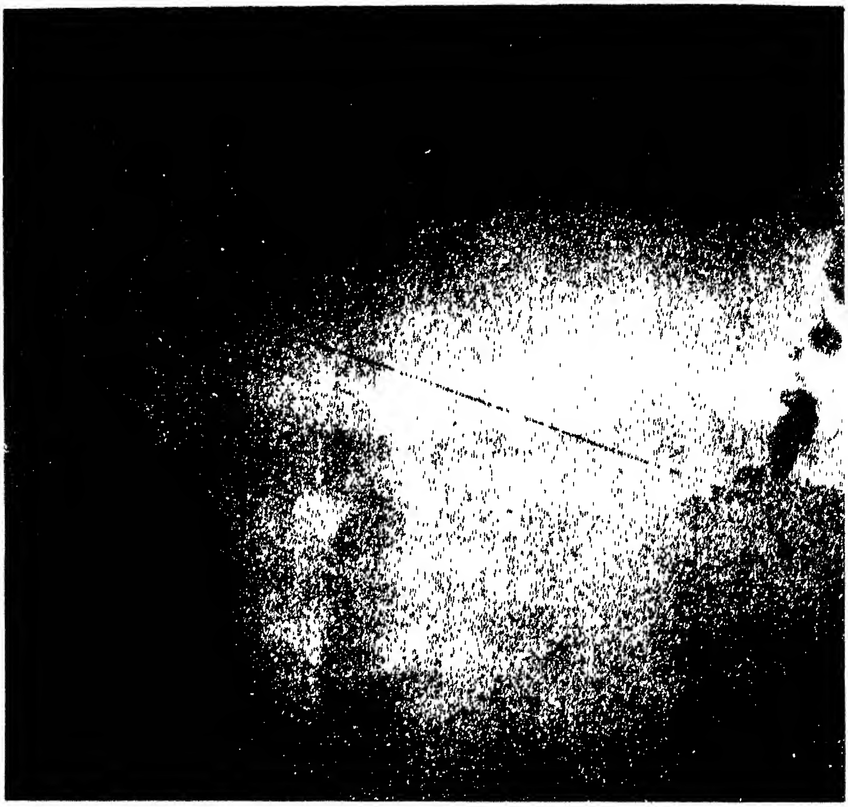


Fig. 430.—Diverticulitis, Twenty-four Hours after Opaque Meal.

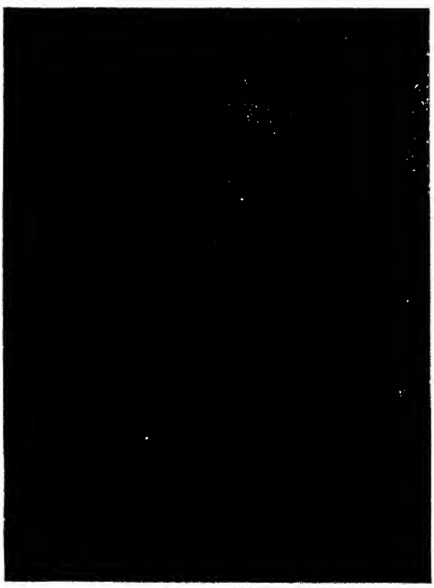


Fig. 431.—Diverticulitis after Opaque Enema.

Fig. 432. - Diverticulitis, Forty-eight Hours after Meal and after Evacuation of Bowel.

Stasis in the ileum, with opaque contents visible longer than twenty-four hours, as in the case from which Fig. 428 was taken, may be so considered, as also *stasis* at the tip of the *cæcum*, *hyperperistalsis* in the stomach, and *spasm* of the *duodenum* or *colon*.

(*f*) **Diverticulitis** may be diagnosed from the appearance of small rounded or oval shadows of the opaque meal or enema lying *outside the lumen* of some portion of the intestine. Those may be connected by a pedicle shadow with the shadow of the bowel content, or they may appear isolated, and an important confirmatory sign of their nature will be the *persistence* of the small shadows long after the main shadow in the bowel has disappeared.

Reproduction of the appearances produced is rather unsatisfactory, but Fig. 430 and Fig. 431 shew the earlier appearances, whilst Fig. 432 shews the persistence of appearances forty-eight hours after an opaque meal and after the bowels had otherwise been evacuated.

There is possible confusion between such shadows and those of calculi, phleboliths, or calcified glands. A plate exposed previous to administration of the opaque meal or enema should prove the presence or absence of such opaque bodies, and, in the absence of that, manipulation of the part will shew whether the isolated shadows move with the bowel (as diverticula must).

Their *constancy* in form and *persistence* after emptying of the bowel should differentiate diverticular shadows from normal markings of the bowel.

Secondary effects such as *narrowing and defective filling* of the bowel and the production of *spasm* resemble those due to carcinoma, and in the event of non-filling of the diverticula differentiation seems impossible.

If the only additional appearance is irregularity of outline of the lumen the *rounded shape* of a diverticulum is not likely to be simulated by carcinoma, but the persistence of such rounded shadows after emptying of the bowel is the only sure differentiating sign.

Any region of the bowel may shew such diverticula, but they are most common distal to the splenic flexure. They may be concealed by the overlying shadow of the bowel content, and their detection therefore may require inspection in many different positions. Stereoscopic views of the appearances may aid in the identification of the cause.

(*g*) **Constipation.**—Three types of constipation have been identified by X-ray observation:—

(i) *Atonic or hypokinetic*, in which the absence of haustral movements are observed, indicating lack of muscle tone and motor stimuli—this may occur in any part of the colon and may be accompanied by ptosis.

(ii) *Spastic or Dyskinetic*, in which excessive motility is observed, including definite anti-peristaltic movements, as revealed by abnormal segmentation and irregular formation of small discrete masses. The lower colon usually fills in normal time, and the irregularity may occur throughout the large intestine or only in one part.

(iii) *Rectal constipation or dyschesia*, in which the colon appears normally active and the rectum is reached in normal time, but delay occurs there, accompanied by extreme degrees of dilatation.

Such observations should be made by means of an opaque meal and an opaque enema, and they should be repeated for confirmation before any definite opinion is expressed, as the differentiation between temporary and permanent appearances may be hard to establish.

(*h*) *Diaphragmatic hernia and Eventration* may be definitely diagnosed and differentiated by the aid of an opaque meal. Those conditions are discussed in an earlier section on the thorax, on page 412.

V. TUMOURS.

Tumours in the Abdomen may or may not be revealed and partially located by their shadow. A radiogram may shew little more than a faintly defined shadow where no shadow should be normally present. A screen examination will give more information by noting the movements of the shadow relative to respiration, and by observing its continuity or otherwise with normal shadows of the region.

The aid of an opaque meal in revealing the presence of tumours causing obstruction of, or interference with, movements of the stomach or intestines has already been indicated.

Pneumoperitoneum.—The introduction of air (or other gas) into the peritoneum to render, by contrast, the detection of tumours more easy has been suggested and practised to a limited extent. The results of the procedure, whilst interesting and at times valuable, have not, however, been such as to make it accepted as a routine procedure.

VI. LIVER AND GALL BLADDER.

Liver.—Abnormal conditions of the **liver** may be revealed; but seldom so plainly as in Fig. 382, on page 442, where a calcified hydatid cyst produces a striking appearance. As a rule, abnormalities are detected only when the shadow projects beyond the normal outline of the liver shadow, since that organ is so dense as practically to defy differentiation. Thus, the presence of *hydatid disease* or *chronic abscess* may be confirmed, but efforts have hitherto failed to diagnose between these two conditions. Fig. 433 reproduces a case of the former.

Gall Bladder.—X-ray examination of the gall bladder is fast becoming part of the routine work of all efficient departments.

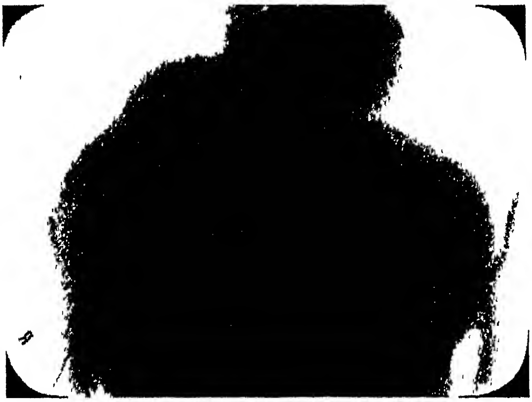


Fig. 433.—Hydatid Disease of Liver.

Gall stones may be diagnosed by presence of abnormal shadows in a large percentage of cases, whilst pathological conditions of the *gall bladder* may be evidenced directly by its appearance on a radiogram or deduced from indirect evidence obtained in examination of neighbouring organs.

(*a*) The *regional anatomy* of the right hypochondrium, and the relations of the gall bladder to neighbouring organs, should be carefully studied, so that the probable position of shadows may be anticipated, and so that effects noted may be traced to their cause.

The gall bladder lies along the under surface of the liver, between the right lobe and the quadrate lobe of that organ; and its fundus projects beyond the lower border of the liver for a

variable, but normally short, distance at a point opposite the angle made by the anterior end of the ninth costal cartilage with the eighth.

It is thus in *relation* on its under side with the hepatic flexure or transverse colon in front, and with the second portion of the duodenum further back.

Its position may vary somewhat with the build and condition of individual patients; its size may vary considerably, especially in pathological conditions, such quotations ranging from "the size of a walnut" to 8 in. in length.

(*b*) In order to make comparison of radiograms reliable a *standard position* should be fixed for this, as for all other regions, and all routine exposures to elicit information concerning the gall bladder or its contents should be made in this position. To clear up any doubtful point, further exposures may then be made in suitable positions as required.

It is most important in radiography of this region that every detail of technique be scrupulously attended to, because diagnosis may depend upon very slight variations in density, which may readily fail to be impressed on a plate carelessly exposed, or fail to be recognised on a plate imperfectly developed or inefficiently inspected.

The *alimentary tract* of the patient should be as *empty* as normally possible at the time of examination, but the abnormal peristalsis of purgation should have ceased before the examination is commenced. An enema in the early morning and abstention from breakfast should precede a forenoon appointment, and opaque drugs, such as bismuth, must not be taken for some days before, otherwise confusing shadows in stomach or bowel may produce dubious appearances. In the presence of any such *doubts* the examination should be *repeated*, and this may be necessary many times before final satisfaction is obtained.

The patient should, as a preliminary, be *screened* in the upright position, so that any abnormalities may be noted, but screen examination is of little or no value in direct diagnosis of gall bladder conditions.

A *tube of fine or medium focus* should be chosen, and usually a tube of "soft" condition, giving rays of penetration not greater than expressed as of 4 in. equivalent spark-gap, or a No. 4 Benoist, is preferred, but some of the best work has recently been done with a 6 in. tube.

For a first exposure the patient should lie *prone* on the X-ray table, with the lower anterior chest wall in close apposition to an exposure cassette, which should be placed so that the right costal margin crosses its middle.

The shoulders may be raised by placing two or three pillows under the clavicles or by raising the forward end of the table top, if that be hinged to allow such adjustment. This position permits closer apposition of the costal margin to the cassette, and also serves to project the gall bladder fundus a little further downwards.

The *tube* should be *centred* vertically over the point described above as the normal site of the gall bladder, namely, the angle of junction of the ninth and eighth costal cartilages. This point may be taken as the mid-point of the costal margin, or, whilst the patient lies face downwards, as vertically under the point where a vertical line bisecting the right side of the chest crosses the twelfth rib.

For purposes of *comparison*, as already noted, this *position* of the tube with its central ray perpendicular to the plane of the cassette should be *rigidly adhered to*, although for further information, under special circumstances, other settings may be employed. Thus, the tube set over the ninth rib behind and tilted so that the central ray passes at an angle parallel to the under surface of the liver, may clear up a doubtful shadow; or, with deformities of the spine, the tube may have to be set so as to make the projected shadow of the gall bladder clear that of the spine.

A *cylindrical compressor diaphragm* of small diameter should be employed, and the area limited to 10 in. by 8 in.

A *Potter-Bucky diaphragm* interposed between the patient and the sensitive plate, as described on page 151, may materially assist the definition of the picture despite the greater space interposed between patient and plate and the longer exposure entailed.

The *exposure* should otherwise be made as brief as possible, since the slightest movement of the patient during that period may render the procedure valueless for diagnosis. *Respiratory movements* must be entirely *inhibited* during exposure, and pains should be taken to explain to the patient beforehand what is required of him. The injunction to him should be negative—to "stop breathing"—and not a positive order to "hold his breath"; since the effort suggested in the latter may defeat the object aimed at.

In addition to exposure in the above standard position, a *lateral view* will often be desirable, especially for differentiation between gall bladder and kidney shadows, as noted later. The patient should lie on his right side with both arms drawn forward, the cassette placed under the right costal margin and the tube set vertically above the mid-point of the left lateral costal margin. The Potter-Bucky diaphragm will here be particularly useful.

A *posterior* setting of the plate may also be required at times for differential diagnosis; this exposure should be carried out as for an exposure of the right kidney, and as explained in the succeeding section.

Gas injection of the peritoneum has been employed to give greater contrast, and might be employed in a critical differentiation, but, as already mentioned, the procedure has never become common nor can it be recommended in routine work.

(*c*) **Gall stones** vary in composition and consistency, and the ease or certainty of their detection by radiography varies accordingly. This is discussed exhaustively in the interesting work, "The Radiological Examination of the Liver, Gall Bladder and Bile Ducts," by Dr. Robert Knox, and reference should be made to those observations. The whole subject is also discussed in a most useful and interesting manner by Dr. George and Dr. Leonard, in Vol. II of the "Annals of Roentgenology."

Abnormal shadows seen in the region of the gall bladder may require differentiation before they are pronounced as due to gall stones, but their positive presence is naturally an important diagnostic point. The absence of any such abnormal shadow cannot however be relied upon as evidence of the absence of gall stones, since those may be so transradiant as to cast no differentiating shadow under the conditions or technique employed for their detection. Repeated exposures may be necessary to secure a radiogram satisfactory enough to justify abandonment of the search when symptoms point to the possible presence of gall stones, and each detail of the preparation of patient, exposure and development should be considered and revised before such a conclusion is reached.

As seen in Fig. 434, a satisfactory radiogram of the gall bladder region should shew the eleventh and twelfth ribs with outlines of the lower dorsal and upper lumbar vertebræ with

L.

R.

Fig. 434.—Gall Stones with Anatomical Landmarks.
(Sides of figure inadvertently reversed.)

Plate LXXXIII.

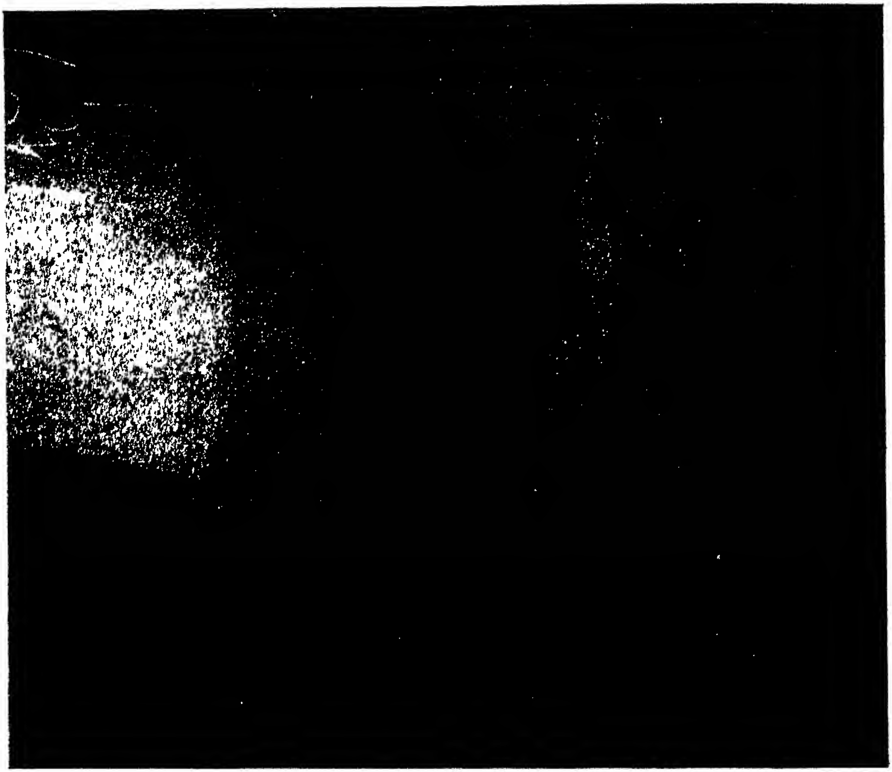


Fig. 435.—Mottled Shadow of Gall Bladder with Multiple Calculi.

Plate LXXXIV.

their transverse processes, but no detail of the structure of their bodies. The kidney shadow may be recognisable, and if so may assist differential diagnosis, but it will be much enlarged and possibly too diffuse for recognition.

The shadows produced by gall stones may be of various characters, depending upon the nature of the stones.

(*a*) The commonest and most characteristic stones are seen as a faint ring produced by the denser periphery of the stones or, as in bone cortex, merely by the tangential incidence of the rays. Those rings may be approximately circular in shape or facetted by mutual pressure, as in Fig. 438.

(*b*) Other stones, usually irregular in shape, shew a *laminated* shadow, as if produced by concentric layers of denser and less dense material.

(*c*) *Homogeneous* shadows may be seen of considerable density, evidently due to stones with calcium more or less evenly distributed in them, and those may closely resemble renal calculi.

(*d*) Shadows *without definite form* may be cast by a number of stones superimposed, none of which are dense enough to produce an individual record; whilst a similar appearance may be produced by accumulation of so-called "sand" or even pathological bile salts. A number of fair-sized soft stones in a gall bladder may produce a *mottled shadow of the bladder*, which is definitely characteristic but not always easy of recognition, especially in stout patients. Fig. 435 reproduces the appearance.

Gall stone shadows must be *differentiated* from:—

(1) *Calcified costal cartilages:* position, irregularity, and bilateral occurrence will usually distinguish and a lateral view will confirm.

(2) *Renal calculi:* denser and more irregular; may be obviously in kidney shadow; lateral view will reveal position on, or posterior to, the anterior border of the vertebral bodies. Exposure as for kidney will produce definite shadow of renal calculi, whereas gall stone shadows will be diffuse to disappearance. Gall stone shadows in a *lateral view* will be definitely anterior to the vertebræ; if in the gall bladder close to the abdominal wall, if in the bile ducts a little further back. Gall stones do not shew the same variety in shape as renal calculi, being usually rounded or facetted, so as to appear polygonal or triangular. Injection of the kidney with an opaque

solution, as described later under pyelography, will serve to differentiate further if necessary.

(3) *Calcified glands*, lymphatic or adrenal: irregular in shape, mesenteric are movable, whilst adrenal in lateral view will be definitely posterior.

(4) *Food or fæcal material* in stomach or bowel should be eliminated by preparation of patient; repeated examination will demonstrate disappearance or change in position.

A Pathological Gall Bladder will probably produce a shadow in a carefully exposed plate. As technique improves a greater number of gall bladder records are obtained, and doubtless in the near future, if not now, records will be obtained on radiograms of normal bladders.

At present it may safely be said that, whilst all pathological gall bladders may not be revealed by radiography, every bladder so revealed may be taken to be pathological, but this generalisation may call for revision at an early date.

The bladder shadow is rounded and definitely outlined, but varies greatly in size and position—usually close under the costal margin, it may be found as low as the iliac crest. This must be differentiated from :—

(1) *Contour of liver edge :* lack of continuity and difference in density will usually appear with a gall bladder, but secondary evidence alone may justify diagnosis.

(2) *Stomach and intestinal contents :* inconstant, as revealed by repeated examination and preparation of patient, or by opaque meal.

(3) *Tumour masses* such as cancer of head of pancreas or pylorus : indefinite outline and secondary evidence will usually distinguish, or pneumo-peritoneum may reveal.

Indirect Evidence of Gall Stones or Pathological Gall Bladder.—In the above notes direct evidence mainly has been discussed, but valuable assistance in diagnosis may be obtained from the *indirect evidence* obtained in the course of examination of the gastro-intestinal tract by aid of an opaque meal. This evidence has already been referred to on page 480, and, as experience increases and special technique improves, greater reliance is being placed upon it.

NOTE.—See *Archives of Radiology and Electrotherapy* for July, 1923.

Fig. 436.—DEFORMITY OF DUODENAL CAP DUE TO PRESSURE OF GALL BLADDER.

Fig. 437.—"HALF-SHADOW" AT PYLORIC END OF STOMACH. (See adjoining text.)

Plate LXXXV.

Fig. 438.—Gall Bladder with Calculi Pressing upon Antrum of Stomach.

Plate LXXXVI.

In such examination of bismuth-filled organs may be noted :—

(1) *Deformity* due to pressure of a pathological gall bladder on the first or second part of the *duodenum* or upon the *antrum* of the stomach. This appears as a concave irregularity on the outline of the viscus, the outline of the concavity being smooth, and the density of shadow in it being graded from the lighter surrounding area to the dense opacity of the opaque meal. This sickle-shaped "half shadow" is said to be pathognomonic of pathological gall bladder. It is best seen in the prone position, and is probably never produced by a normal gall bladder or by other conditions such as irregular contour of liver, enlarged movable kidney, or new growth. Fig. 418 on page 478, and Figs. 436 and 437 shew the appearance referred to, and Fig. 438, in which the gall bladder contains calculi, illustrates the method of production of the deformity.

(2) *Adhesions* to adjoining parts of the intestine produce characteristic *filling defects*, usually in the first portion of the duodenum, where it is best seen when the stomach is full, as contrasted with the appearance produced by an ulcer, which is best seen when the stomach is nearly empty. Other parts of the bowel may be affected, namely, the second portion of the duodenum, the jejunum, or the colon in the region of the hepatic flexure. Those appearances and effects are discussed in earlier sections dealing with the various regions referred to.

(3) *Reflex spasms* may be produced in the gastric movements, a common appearance being a tubular spasm of that part of the stomach adjoining the pylorus. This appearance is suggestive, but of little, if any, isolated importance.

(4) The *ampulla of Vater*, where the biliary and pancreatic ducts enter the intestine, may admit and retain a portion of the opaque meal, and will be seen as a small isolated bead or plug of dense shadow which retains its position. A similar appearance may occur with a diverticulum or an ulcer, but, apart from those, probably never appears with a healthy gall bladder and pancreas, and will therefore serve to suggest further investigation of those organs.

CHAPTER XIII

DIAGNOSIS—URINARY SYSTEM

Kidneys—Ureters—Bladder

IN the *kidneys* the usual quest is for calculi. In a person of ordinary girth evidence of a renal calculus may be confidently expected if one be present, provided that careful attention be paid to the points noted later. The composition of the calculus determines to some extent the likelihood of its casting a perceptible shadow. Calculi containing oxalate of lime, phosphates, or cystine cast shadows readily observed, whilst uric acid or urate of ammonia calculi are so transradiant as to be readily missed. Where the evidence of a radiogram is positive the diagnosis may be confidently relied upon, but where negative it should be doubted, unless all the landmarks prescribed later are clearly defined. With a reliable radiogram a surgeon will hesitate to operate if its evidence be negative, even though symptoms are indicative of the presence of a calculus, for, unless in the rare case of a pure uric acid calculus, a good radiogram is not likely to fail to shew some evidence. Besides confirming the diagnosis of its presence, the location of the calculus may considerably reduce the severity of the operation for its extraction. A screen examination can in no case be relied upon for final evidence of the presence or absence of a renal calculus.

The *bladder and ureters* may be similarly investigated for presence of *calculi*. In the latter position stereoscopic views are preferable to locate the calculus; in the former the calculus is, of course, movable, and its detection is sufficient.

Kidneys.—Before proceeding to radiograph this region it must be made sure that the patient has had the *bowel thoroughly emptied;* otherwise confusion of shadows is likely to result. It is better to postpone the exposure than to proceed with the bowel possibly occupied by fæcal masses, which may simulate, or at least confuse the evidence of, the presence of calculi.

A dose of castor oil forty-eight hours before examination should be followed by an enema, but this should be arranged so

that the bowel is quiescent again before the examination is undertaken. Some details of preliminary technique for radiography of this region are described on pages 151 to 155, and, to avoid repetition, the reader should refer to those pages.

The patient may be placed to lie either on his face or on his back (as discussed in the pages referred to), the X-ray tube being in either case placed opposite the front of the abdomen, while the plate is placed in close apposition to the back.

Tube under table.—For the former position the patient should be placed on the table, lying with his face downwards, and the tube placed below. Under him, crossing the space between the iliac crests and the lowest ribs, may be placed a cylindrical air-

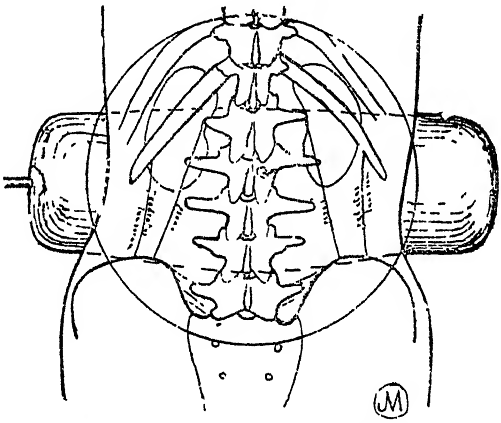


Fig. 439.—POSITION FOR KIDNEY.
(For cylindrical air-cushion substitute central pad as described in text.)

pillow, as shewn in Fig. 439, but the wedge series of cushions described on page 153 serve better. This diminishes the forward lumbar curve and presses the kidneys backward, whilst it further serves to restrict their movement which normally occurs in consonance with the respiratory movements of the diaphragm. Guided by the view on a fluorescent screen, the tube should be adjusted till an area is illuminated, as shewn by circle in Fig. 439, which includes a narrow portion of the iliac crests and the two last ribs on each side.

The screen should then be replaced by a large plate, 10 by 12 in. (or larger if desired), and this held firmly in position by pressure while an exposure is made.

This pressure may be suitably exerted by a rigid flat board, faced with lead, and on that further pressure may be added manually or by means of a compression strap. The patient's

weight acts, of course, as a compressing force on the part bearing on the cushion, and by this method excellent radiograms may be produced in the absence of any special means of compression.

Tube above table.—The more usual method of exposure is with the patient on his back and the tube set above, as in Fig. 440. In this position some form of mechanical compression is necessary. The use of *such* compressors is described and discussed on page 152, and their use has become very general. A compressor should always be supplemented in radiography of the kidney region by the use of the wedge series of pads already referred to. Those pads should be applied over the

Fig. 440.—POSITION FOR RADIOGRAPHY OF KIDNEY.

abdomen in the middle line, well up towards the episternal notch, if both kidneys are being included in the radiogram. If one kidney only is to be exposed, they should be placed a short space below the lowest rib on the corresponding side, just within the nipple line. The smallest pad is placed on the skin and progressively larger pads placed over it. The compressor should be applied so as to exert pressure on the abdomen upwards and backwards, thus displacing or compressing the intervening viscera and also inhibiting or reducing diaphragmatic movement.

As noted in the chapter on "Photography," it is advisable to use a moderately soft tube, or otherwise a calculus—especially if it be of a softer variety—may be entirely penetrated, and no record of it be left on the sensitive plate.

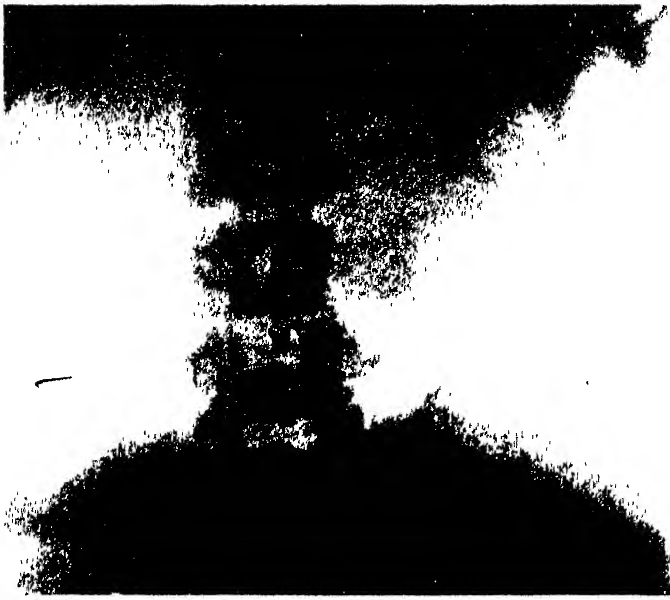


Fig. 441.—Single (Triangular) Calculus in Kidney.

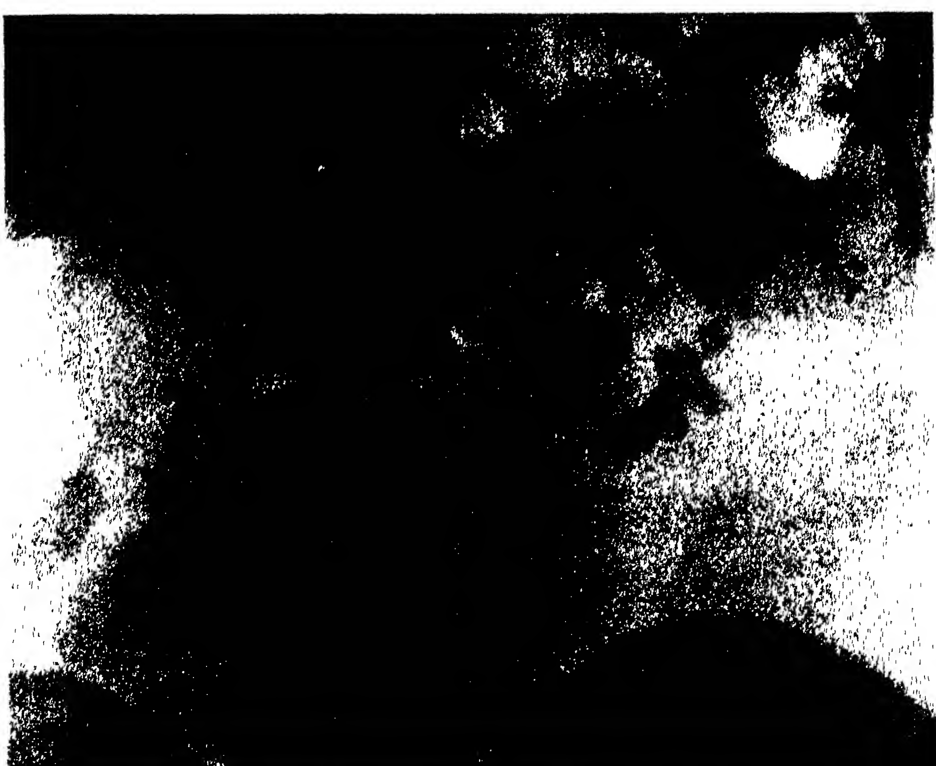


Fig. 442.—Group of Calculi in Kidney.

Fig. 443.—GROUP OF CALCULI WITHIN KIDNEY OUTLINE.

Fig. 444.—CALCULUS WITH LESS DEFINITE SHADOW.

Fig. 445.—CALCULUS IN URETER.

Fig. 446.—CALCULUS IN BLADDER.

In all cases of query regarding any part of the urinary system, a preliminary survey should be made of the *whole tract*. With a Potter-Bucky diaphragm this may be done by one exposure on a large-sized plate, and later attention directed towards any suspicious locality. If the ureters and bladder cannot be so included it is at least essential to include both kidneys in one view for the sake of comparison, and also because symptoms cannot be relied upon as a true index of the situation of the lesion. Much after-confusion may be saved here by remembering the earlier instruction to place on one definite corner of the plate a metallic object which will be imprinted on the plate during exposure, so as to ensure that right and left sides may subsequently be differentiated without hesitation.

Fig. 441 is from a radiogram shewing a triangular stone in the right kidney, whilst Fig. 442 shews an easily recognisable group of calculi.

In a reliable radiogram of this region there should be discernible on each side shadows of the *iliac crest*, of the two last *ribs*, of the *quadratus lumborum muscle*, and of the *psoas muscle*. The *transverse processes* of the vertebræ should also be traceable, but no details of the vertebral bodies. The *kidney outline* may or may not be visible, but if the other four landmarks are not traceable the radiogram should not be relied upon. Fig. 439 shews diagramatically the landmarks mentioned.

If one kidney shews abnormality in the larger plate, and a more defined picture be desired, a plate should later be exposed over that side with the tube centred, and the diaphragm contracted, to include the abnormal organ alone. Many radiologists prefer, as a routine method, to expose a series of smaller plates—usually five in all—one over each kidney region, one over the upper and middle region of each ureter, and one to include the lower ureters and bladder.

Fig. 443 reproduces such an exposure, in which the kidney outline is recognisable enclosing a group of calculi.

Fig. 444 is from a less easily detected case, and such cases commonly tax the discernment of the radiologist considerably. Diagnosis may have to be made on much less definite shadows than any of those reproduced here, but to illustrate such cases would be futile, since the faint shadows would be entirely obscured in reproduction.

If there is doubt in the diagnosis, a second examination should be made after some days, during which time thorough evacuation of the bowel should be secured by purgatives supplemented by a high enema.

Fallacies.—This second examination should obviate possible mistakes due to presence of *material in the bowel*, such as opaque salt residues, since those will be changed in position if not entirely removed.

Differentiation from *gall stones* has been described in the preceding section.

Calcified glands are usually identified from their position, which may be seen to alter.

The tip of a *transverse process* may overlie a kidney, or a *phlebolith* may similarly cause confusion, but those, along with appearances produced by growths or dressings on the *skin* of the back, should be readily differentiated if remembered.

Artefacts in the plate due to faulty emulsion or unequal development should also be remembered as possible fallacies.

The original negatives only can be relied upon for results, as appearances discernible on those may be incapable of reproduction on prints.

Ureters.—Radiography of the ureters presents some difficulty, and results of search for calculi in them are at times somewhat uncertain. If present towards the higher end of the ureters, calculi may be detected in a plate exposed as directed for the kidneys. The lower parts must be exposed differently in order to clear the pelvic shadow, as described for the positions mentioned below for radiographing the bladder. Calculi are most commonly found towards one or other end of a ureter.

Other structures in the region of the ureters may cause doubt and confusion in interpreting a radiogram.

Thus, *calcified glands* along the border of the vertebral shadow or in the pelvis, as well as *phleboliths* in the veins or calcified portions of arterial walls, may simulate the appearance of calculi.

Ureteric stone shadows may be distinguished from conditions which simulate them by noting that they lie *in the line of the ureter*, their *outlines* are *not very sharp*, their *shapes* are more or less oval, and their *density* is *fairly even* throughout.

Calcified glands, by contrast, are of *sharp outline*, and usually shew a *less uniform density*. Being situated at the root of the mesentery, they lie in a line from the left kidney to the right

sacroiliac region, whilst comparison of successive exposures may shew a distinguishing *change in their position.*

Phleboliths are usually *circular* and *multiple*, of *sharp outline*, and situated *under* and *external* to the course of the ureter.

To eliminate confusing shadows an *opaque bougie* may be passed up the ureter or an injection made of some solution partially opaque to X rays, as described later in a section on *pyelography*. The relation of the suspected shadow to that of the bougie or salt lining the ureter may then be noted. Stereoscopic views of the part, especially with bougie or opaque salt in position, assist the diagnosis and location materially.

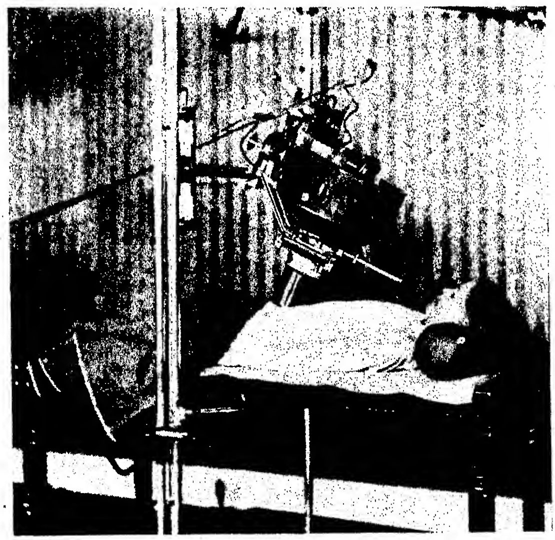


Fig. 447.—POSITION FOR BLADDER WITH TUBE ABOVE.

The *course of each ureter* from the kidney pelvis downwards, crossing the transverse processes of the lumbar vertebræ and the sacroiliac joints, and passing thence inwards and forwards to enter the bladder, should be borne in mind when examining radiograms of any part of their course.

That course may be noted in several of the pyelograms reproduced later, and one of those shews a calculus impacted in the ureter, thus illustrating the value of such opaque injections.

Bladder.—For a joint view of the *bladder* and lower part of the *ureters* the patient may be placed on his back, and the tube set below so as to throw its central ray upwards in a direction roughly corresponding with the axis of the brim of the pelvis, or the tube may be set above the patient with its central ray directed downwards in the same axis, as represented in Fig. 446. The bony walls of the pelvic cavity thus form a kind

of frame surrounding a space more or less completely occupied by the bladder, as seen when projected on a plane roughly parallel with the brim of the pelvis.

With the *tube below* it must be set with its centre close to, and about an inch beyond the tip of, the coccyx, and with that end of the tube towards the patient's feet raised a little, as shewn diagramatically in Fig. 447; and a plate, 12 in. by 10 in., should then be placed over the abdomen, with its length across, its upper edge about the level of the umbilicus, and its lower edge slightly overlapping the symphysis pubis. The movements with respiration of the upper edge of the plate should be

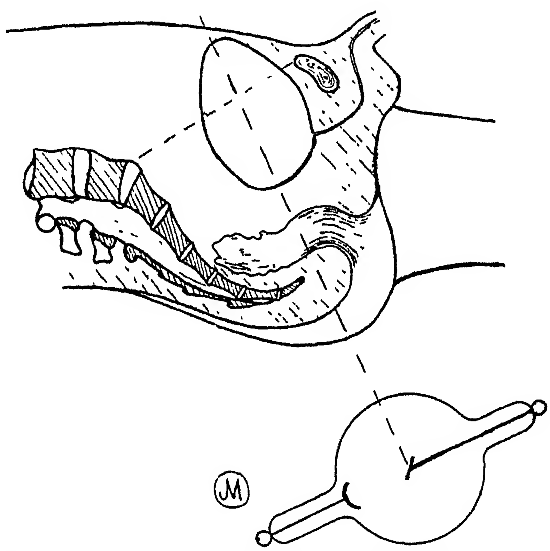


Fig. 448.—POSITION FOR BLADDER WITH TUBE BELOW.

inhibited by exerting pressure on it, either manually, by superimposed weight, or by strapping.

With the *tube above*, the plate will be placed under the buttocks, and compression may be exerted directly over the bladder by one of the mechanical compressors, described on pages 151 to 155, as for use over the kidneys.

This latter position has the advantage of securing steadiness of the plate, whilst movements of the bladder and ureters during ordinary respiration may practically be ignored.

For the bladder alone the patient may be laid on his face and the plate placed under him, since by gravity a calculus will then come to lie in close apposition to the plate. Abdominal movement will be somewhat inhibited and the plate will remain stationary. The same directions as to setting of the tube and

plate relative to the patient apply here as in the other position, and if the patient's own weight be not considered sufficient for compression, a transradiant band may be passed across his back and fastened to each side of the table so as to exert pressure.

The form of outline of the shadow obtained will vary with the age and sex of the patient; but the endeavour should be to secure in the centre as large and as clear a space as possible, representing the cavity of the pelvis. Fig. 448 shews the form of shadow usually obtained under average conditions, the figure being reproduced from a radiogram of a calculus in the bladder.

Aids to Examination.—The use of *opaque bougies* in the

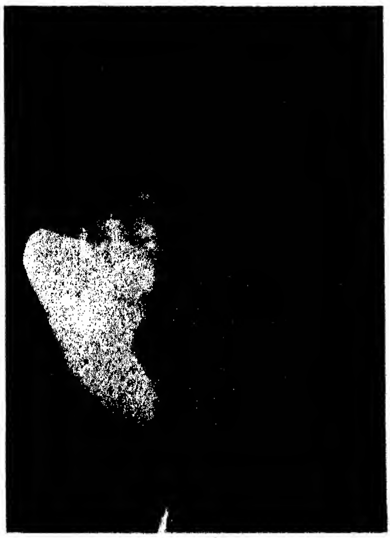


Fig. 446A.—Calculus in Bladder.

ureters has already been referred to. In examining the region of the *bladder and lower ureters*, assistance may be obtained by *filling the bladder with air*, which makes the pelvic space more transradiant, and indicates the outline of the bladder on the radiogram. This may be done by merely passing a catheter and elevating the pelvis, but is seldom resorted to.

To facilitate examination of a *kidney*, it was suggested by Carelli and others to pass a hollow needle into the *perirenal fat*, and so to *inflate* that tissue with *oxygen* or *carbonic oxide*. The outline of the kidney, and particularly of the *suprarenal capsule*, is thus well shewn, and the presence of a *tumour* may be strikingly demonstrated, but no assistance is obtained in diagnosing the internal condition of the organ. For that purpose the auxiliary use of *salts opaque to X rays* has been extended to the study of the kidneys and ureters.

This process, termed *pyelography*, is not without its dangers. Deaths have been reported from it, being ascribed by some to the poisonous effects of the salts used, by others to the mechanical effects of over-high pressure in the pelvis of the kidney. Collargol solution was for a time commonly used, then alternatives were proposed, such as thorium nitrate (10 per cent.) with sodium citrate, silver iodide, potassium iodide, and, latterly, a sterilised solution of sodium bromide of 20 per cent. strength for kidneys and 10 per cent. for bladder.

This is said to be non-toxic, but possibly irritant in such

Fig. 449.—PYELOGRAPHY IN NORMAL KIDNEYS.
(Reproduced from Braasch's "Pyelography," by kind permission of Messrs. W. B. Saunders.)

cases as chronic cystitis, for which a 10 per cent. suspension of colloidal silver may be preferred.

Fig. 449 shews appearances obtained in normal kidneys, and various points regarding the shape, position and condition of those organs may be strikingly demonstrated. No case should, however, be undertaken by a radiologist unless under the supervision, and with the active assistance, of a surgeon with special experience of the region concerned. The technical points special to the process are entirely the business of the surgeon, so need not be described here. Those are interestingly dealt with in a paper by Mr. F. Kidd, in the *British Medical Journal* for 13th May, 1922, and a few of the radiograms illustrating that paper are here reproduced.

A later paper, by Sir J. Thomson Walker, is printed in the "Archives of Radiology and Electrotherapy" for April, 1923.

Fig. 450.—Normal Kidney.

Fig. 451.—Kidney with Double Ureter.

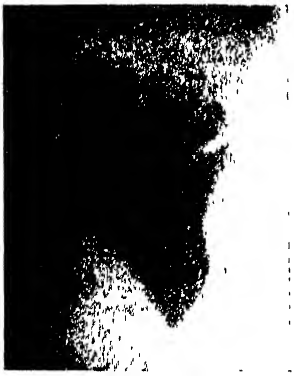


Fig. 452.—Hydronephrosis.

Fig. 453.—Displaced Kidney with Kink in Ureter.

Fig. 454.—Calculus Impacted in Ureter.

Fig. 455.—Bladder with Pouches.

Typical Pyelograms.

Fig. 456.—Fœtus in Utero.

(*See note opposite.*)

APPENDIX NOTE.

Radiology in Obstetrics:—Fig. 456 opposite represents the latest essay in radiological diagnosis, an essay which promises to be of critical importance to the obstetrician.

With proper technique reliable records of the unborn child and its relation to the maternal pelvis may be obtained after the term of six months. Earlier records are more difficult to obtain on account of the cartilaginous, and therefore transradiant, condition of the fœtal skeleton.

Factors of difficulty and uncertainty are introduced by the maternal vertebræ, the thick vascular uterine walls, and the liquor amnii enveloping the fœtus, but the use of a Potter-Backy diaphragm, as explained on page 151, overcomes most of those difficulties.

With the mother lying face downwards, and the chest, or chest and pelvis, supported if necessary on pillows, radiograms may be so obtained which will positively settle any doubt as to presence of twins or as to the lie of the child. Obstetricians will doubtless find other points upon which radiography can thus lend them assistance.

Without a Potter-Bucky diaphragm some information may be gained from a radiogram produced on a film placed under the protruding abdomen of the mother while she lies on her side with the tube set above so as to send its rays through the uterus laterally. The value of such a radiogram is very limited, however, as compared with the postero-anterior view made possible by the special technique noted above.

Little has so far been published on this subject, although several radiologists have been occupied on it during the past two years.

An article by Dr. Candy, with illustrations, appears in the *Archives of Radiology and Electrotherapy* for October, 1923.

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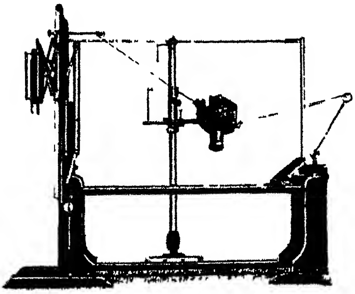
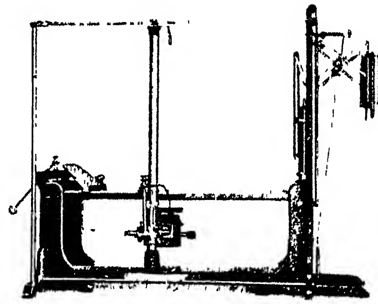
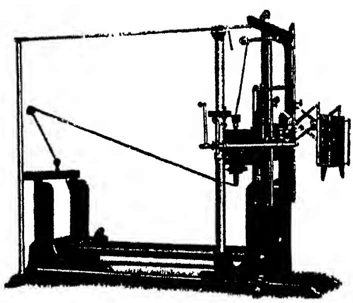
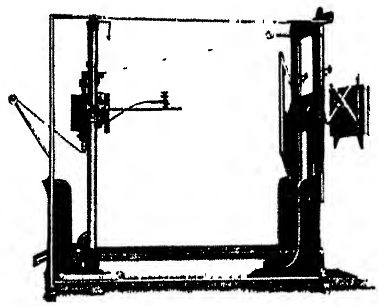

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